CARNEGIE INSTITUTION

OF

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YEAR BOOK

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OFFICERS FOR THE YEAR 1906.

* Ex-officio member.

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ARTICLES OF INCORPORATION.

The Carnegie Institution was originally organized under the law governing the organization of corporations in the District of Columbia. Owing to certain limitations in the law, the Trustees deemed it desirable to obtain articles of incorporation from the Congress. Accordingly, articles of incorporation were prepared, submitted to the Congress, amended by the Congress, and enacted into statute by the Congress and the signature of the President.

Organization under the new articles of incorporation was effected on May 18, 1904. Resolutions were passed electing the same Executive Committee and officers as those of the Carnegie Institution organized in 1902 and continuing all instructions and authorizations given to the Executive Committee by the old organization.

PUBLIC NO. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common

seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over,

and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. No person shall be elected, however, who shall not have been nominated at a preceding annual or special meeting, except by the unanimous consent of the members present at a meeting.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the second Tuesday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term ; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized. He shall have custody of the seal of the corporation and shall affix the same whenever authorized to do so by the Board of Trustees or by the Executive Committee or the Finance Committee.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of all property of the Institution whose custody is not otherwise provided for. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz, an Executive Committee and a Finance Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have general charge of the investments and funds of the corporation, and shall care for and dispose of the same subject to the directions of the Board and of the Executive Committee. It shall consider and recommend to the Board of Trustees such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting.

8. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Chairman of the Board, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property shall be deposited in such safe deposit or other corporation and under such safeguards as the Trustees and Executive Committee shall designate; and the moneys of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

Third Meeting of the Board of Trustees.

MINUTES OF THE THIRD MEETING* OF THE BOARD OF TRUSTEES

[Abstract.]

The meeting was held in Washington, at the New Willard Hotel, on Tuesday, December 12, 1905, at 10 o'clock a. m. At 1 p. m. a recess was taken until 2 p. m.

The Chairman, Mr. John S. Billings presided.

The Secretary called the roll and the following Trustees were present: Messrs. Billings, Cadwalader, Dodge, Gage, Gilman, Higginson, Hitchcock, Hutchinson, Lindsay, Low, MacVeagh, Mills, Mitchell, Morrow, Root, Walcott, White, and Wright.

Mr. Andrew Carnegie, the Founder of the Institution, and Mr. Robert S. Woodward, President of the Institution, were also present.

The following Trustees were absent: Messrs. Agassiz, Frew, Howe, Langley, and Spooner.

The Minutes of the last meeting of the Board were presented, and on motion full reading was dispensed with and they were approved as per abstract furnished each member.

The death of Mr. John Hay, Trustee and member of the Executive Committee, was announced. Mr. Elihu Root was requested to prepare a memorial of Mr. Hay for insertion in the minutes of the meeting.

The reports of the President, of the Executive Committee, and of the heads of departments and grantees of the Institution were received and considered.

The Secretary of the Executive Committee explained various details of business transacted by the Committee during the year, and submitted the cash and financial statements, which are shown on pages 38 and 39.

The resignation of Professor Alexander Agassiz as a Trustee of the Institution was presented and accepted.

President Robert S. Woodward was elected a Trustee to fill the vacancy in the Board caused by the resignation of Mr. Agassiz.

The resignation of Mr. Charles D. Walcott as Secretary of the Board was presented and accepted, and Mr. Cleveland H. Dodge was elected to succeed Mr. Walcott.

* The third under act of incorporation (see note at head of page 1).

Mr. Elihu Root was elected a member of the Executive Committee, to succeed himself, and Mr. Walcott was elected a member of the same committee in the place of Mr. Hay.

After discussion, the following general appropriations were made:

Publication fund, to be continuously available	$50,000
Administration	50,000
Grants for departments and large projects	552,600
Grants for miscellaneous researches, including grants previously implied	134,000
	$786,600

At 4 p. m. the Board adjourned.

Memorial.

The Trustees of the Carnegie Institution of Washington direct that a Minute be made in the permanent records of the Institution expressive of their sorrow for the loss of their associate John Hay, who died on the first day of July, nineteen hundred and five, while holding the office of Secretary of State of the United States.

Mr. Hay was one of the small body of gentlemen who gave their aid and counsel to Mr. Carnegie in maturing and inaugurating the plans of the Institution; he was one of the original incorporators and was, from the beginning, a Trustee and a member of the Executive Committee. His catholic interest in every cause that makes for the good of mankind found a ready place for genuine and active sympathy with the work proposed by Mr. Carnegie, and, although burdened by official cares to the limit of his strength, he gave to that work invaluable time and thought and the strength of his noble character and his great name. The peculiar charm of his companionship made the most tedious task undertaken with him agreeable. We have all of us lost a personal friend, and science has lost a powerful ally and patron.

REPORT OF THE PRESIDENT

CARNEGIE INSTITUTION OF WASHINGTON.

REPORT OF THE PRESIDENT OF THE INSTITUTION.

Introductory Statements.

In compliance with the provisions of Article IV of the By-Laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the work of the Institution during the fiscal year ending October 31, 1905, along with recommendations of appropriations for work during the succeeding year, and with some suggestions concerning the future course and progress of the Institution.

Coming as the writer has to the presidency of an institution already well organized, but still in the earlier stages of its development, it is essential for the purposes of a report to assume as a point of departure the plan and scope of operations found well under way. Accordingly, the résumé of the work of the year given below is an account of work planned substantially by the Executive Committee of the preceding year. Similarly, the recommendations made with respect to the ensuing year are mainly in accord with the lines of policy hitherto followed by the Executive Committee. The additional experience of this year seems to confirm, especially, the wisdom of concentrating the resources of the Institution on a small number of large projects rather than on a large number of small projects. Concerning this mooted question, however, some observations will be found in a later section of this report. As regards the larger aspects of the work of the Institution, this report aims to give only a few suggestions derived from a preliminary reconnaissance of the fields of activity already entered. A survey of these fields, not to mention other promising fields of activity, will obviously require more than the available time of one year.

Existing Plan, Scope, and Mode of Administration of the Institution.

As a matter of record, and as a matter of information to the general public, which takes an enlightened interest in the affairs of the Institution, it seems desirable to explain briefly, in this connection and at this epoch, the plan, scope, and mode of administration of those affairs. Referring to the Articles of Incorporation and By-Laws, published on pp. 1–8 of this volume, for a full statement of the objects of the Institution and the rules adopted for its administra-

tion, the fields in which its activities are now concentrated may be summarized under four principal heads, namely:

First, large projects, whose execution requires continuous research, usually by a corps of investigators, during a series of years. Ten such projects are already under way.

Secondly, small projects, which are usually carried on by individual experts during a limited period of time. About three hundred grants in aid of such projects have thus far been made.

Thirdly, tentative investigations, carried on by young men and women who have shown aptitude for research and have desired to pursue specific problems for one or two years. A limited number of persons have been aided by the Institution in this line of work in the hope that some of them might develop exceptional abilities.

Fourthly, considerable sums of money have been allotted annually for the publication of meritorious works which would not otherwise be readily printed, and for the publication of the reports and results of the investigations carried on under the auspices of the Institution. This promises to be a fruitful field of activity. About forty volumes of works in diverse fields have already been issued.

Briefly described, the administration of the Institution is vested in a board of trustees, which meets annually. During the intervals between the meetings of the Board of Trustees, the affairs of the Institution are conducted by an executive committee, chosen by and from the trustees, acting through the President of the Institution as chief executive officer.

Financial Statement for the Year 1904–1905.

The following table shows the balances brought forward from previous appropriations; the amounts appropriated for the year 1904–05 by the Board of Trustees at their meeting of December 13, 1904; the revertments during the year; the totals available for expenditure during the year; the allotments for the year, and the unallotted balances for large grants, minor grants, research assistants, publication, and administration, respectively:

	Unallotted Oct. 31, 1904.	Appropriation, Dec. 31, 1904.	Revertments, Oct. 31, 1904, to Oct. 31, 1905.	Total.	Allotments.	Balance unallotted Oct. 31, 1905.
Large grants	$4,250.00	$310,000	....	$314,250.00	$304,500.00	$9,750.00
Minor grants	230.68	148,000	$6,692.33	154,923.01	130,625.00	24,298.01
Research assistants	....	20,000	....	20,000.00	10,400.00	9,600.00
Publication	24,683.49	40,000	4,474.73	69,158.22	29,388.15	39,770.07
Administration	18,195.59	50,000	150.00	68,345.59	36,868.92	31,476.67
Totals	47,359.76	568,000	11,317.06	626,676.82	511,782.07	114,894.75

The following list shows the departments of investigations to which the larger grants were assigned and the amounts of those grants:

Station for Experimental Evolution	$12,000
Tortugas Marine Biological Laboratory	15,700
Desert Botanical Laboratory	6,000
Horticulture	10,000
Economics and sociology	30,000
Terrestrial magnetism	25,000
Historical research	14,000
Solar observatory	150,000
Geophysical research:	
A. L. Day	15,000
G. F. Becker	7,500
F. D. Adams	1,500
Nutrition:	
F. G. Benedict	7,500
T. B. Osborne	4,000
R. H. Chittenden	2,500
L. B. Mendel	2,000
Paleontology (transferred to minor grants)	1,800
Total	304,500

The fields of investigation to which the minor grants were assigned, the names of the grantees, and the amounts of the grants are shown in the following list:

Anthropology:	
Dorsey, G. A.	$3,000
Archeology:	
Pumpelly, R.	26,000
American School of Classical Studies:	
Athens	2,500
Rome	2,600
Astronomy:	
Boss, L	6,000
Campbell, W. W	3,000
Davis, H. S.	1,500
Newcomb, S.	2,500
Do.	5,000
Bibliography:	
Index Medicus.	
Botany:	
Cook, O. F.	2,000
Spalding, V. M.	600
Swingle, W. F	1,500
Lloyd, F. E.	500
Chemistry:	
Bancroft, W. D.	1,000
Baskerville, C.	2,000
Baxter, G. P.	1,000
Jones, H. C.	1,000
Morse, H. N.	1,500
Noyes, A. A.	2,000
Richards, T. W	2,500
Geology:	
Chamberlin, T. C.	$6,000
Willis, Bailey	2,475
History:	
Wright, J. M.	250
Phillips, U. B.	300
Haskins, C. H.	1,000
Paleontology:	
Case, E. C	800
Hay, O. P.	1,800
Wieland, G. R.	1,500
Philology and linguistics:	
Flügel, E	7,500
Hempl, G.	1,000
Scripture, E. W.	2,700
Physics:	
Barus, C.	1,000
Burgess, C. F.	2,500
Wood, R. W.	1,000
Woodward, R. S.	3,000
Nichols, E. L.	1,000
Zoölogy:	
Castle and Mark	600
Howard, L. O.	3,000
Marine biolog. laboratory.	10,000
Naples zoölogical station.	1,000
Tower, W. L.	1,500
Pearl, R.	1,250
Duerden, J. E.	750
	130,625

The following table shows the fields of investigation, the names of research assistants, and the amounts of their grants:

Field of investigation.	Names of research assistants.	Amount of grants.
Anthropology	Jones, W.	$1,000
Botany	Olive, E. W.	1,000
Chemistry	Sill, H. F., and Zerban, Fritz	1,000
History	Scott, G. W.	1,200
Physics	Whitehead, J. B.	1,200
Zoölogy	Lutz, F. E	1,000
	Shull, G. H.	1,000
	Johnson, R H	1,000
	Morse, A. P.	1,000
Total		10,400

The sources and the amounts of the revertments during the year are as follows:

REVERTMENTS FROM NOVEMBER 1, 1904, TO OCTOBER 31, 1905.

Minor grants:		
O. P. Hay, from large grants	$1,800.00	
Southern and Solar Observatory, grant No. 70	657.38	
Archives United States Government in Washington, grant No. 28-B	984.12	
E. S. Shepherd, grant No. 176	250.00	
R. S. Woodward, grant No. 282	3,000.00	
G. Stanley Hall, grant No. 61	.83	
		$6,692.33
Publication:		
W. O. Atwater	1,900.00	
J. W. Baird	8.25	
W. W. Coblentz	474.91	
H. S. Conard	679.22	
J. E. Duerden	251.40	
H. S. Jennings	10.85	
A. P. Morse	27.85	
George H. Shull	51.89	
N. M. Stevens	64.60	
A. C. McLaughlin	1,005.76	
		4,474.73
Administration:		
300 copies publication No. 16, University of Pennsylvania		150.00
		11,317.06

RÉSUMÉ OF WORK OF THE YEAR.

The Larger Projects.

One of the tasks the President has undertaken is that of conferring personally with all investigators at work under the auspices of the Institution and inspecting all laboratories, observatories, or other establishments where projects of the larger type are under way. Since there have been about three hundred and sixty men and women at work under grants during the past year, and since they reside in widely separated localities, it has been impossible to complete this task in the three hundred days thus far available for the work. Nearly all of the more important establishments have been visited, however, and conferences have been held with nearly all of the investigators.

Considering the wide range and the technical character of the researches of these investigators, it would be presumptuous to attempt in a general report anything more than a summary of their work, and this summary may be brief, since the reports of individual investigators, which will be found on pp. 51–52 of this volume, are designed to give all needed details.

Specially worthy of mention in this connection are the ten larger projects now under way. Without seeking to designate them by inelastic terminology, for they are in a process of development, they may be classified departmentally as shown in the following list, which gives also the names of the principal investigators conducting these works of research :

Experimental evolution in biology : Charles B. Davenport.
Marine biology : Alfred G. Mayer.
Desert plant biology : D. T. MacDougal and F. V. Coville.
Horticulture : Luther Burbank.
Economics and sociology : Carroll D. Wright.
History : Andrew C. McLaughlin and J. F. Jameson.
Geophysics : F. D. Adams, George F. Becker, and Arthur L. Day.
Nutrition : F. G. Benedict, R. H. Chittenden, L. B. Mendel, and T. B. Osborne.
Solar physics : George E. Hale.
Terrestrial magnetism : L. A. Bauer.

Of these departments of research, four have semi-permanent quarters constructed or under construction by the Institution. These are the Station for Experimental Evolution in Biology at Cold Spring Harbor, Long Island, New York, in charge of Prof. Charles B. Davenport; the Marine Biological Laboratory at Dry Tortugas, Florida, in charge of Dr. Alfred G. Mayer; the Desert Botanical Laboratory at Tucson, Arizona, at present in charge of a non-resident

committee of advisers, Dr. D. T. MacDougal and Mr. Frederick V. Coville, and the Solar Observatory now under construction on Mount Wilson, near Pasadena, California, and in charge of Prof. George E. Hale. Although these departments are barely started, and necessarily require additional time for the formative stages, they are already producing noteworthy results and need only the energetic application of patience and persistence to insure contributions to knowledge of prime importance.

Biological Investigations.

The observational and experimental work undertaken in animal and plant biology is of a fundamental character, and is contemplated, it is thought, according to a scale adequate for the solution of the very difficult problems presented. The systematic study of these for a series of years can hardly fail to yield results of signal practical and theoretical value. Several publications with reference to these investigations have already been issued and others will soon be ready for publication. The advantages for research in botany and zoölogy afforded by our biological stations are attracting the attention and stimulating the activity of eminent investigators. Several of the leading zoölogists of America availed themselves during the past summer of the facilities for the study of marine fauna afforded by the laboratory at Tortugas, Florida. Similar use has been made of the opportunities presented by the station at Cold Spring Harbor, New York; while the Desert Botanical Laboratory, by reason of the novelty and the probable economic importance of its work, is an establishment of profound interest alike to the scientific and to the general public.

Horticultural Experiments.

The horticultural experiments and the remarkable achievements of Mr. Luther Burbank are well known in a popular way, though it must be said that the more important aspects of his work remain yet to be interpreted to men of science as well as to the interested public Owing to the impracticability, during the past year, of securing the services of a trained biologist, the preparation of a scientific account of the ways, means, methods, and results of Mr. Burbank's work has been delayed. He has continued his experiments, however, as related in his report, and it is hoped that the necessary arrangements for securing the scientific account of his work contemplated by the Board of Trustees will not be long deferred. Little short of five years will be required for this work if it is done thoroughly well.

As will be seen from the report of Dr. Wright, the Department of Economics and Sociology has undertaken a comprehensive project which should bring, in a few years, extensive contributions to the social and economic history of the United States, and probably also equally important data for a forecast of American social and economic development. The goal of science is capacity for prediction, and although economic and social science are still sometimes regarded as somewhat "dismal" in comparison with the older science of astronomy, for example, they are plainly destined to play an increasingly important rôle in the progress of mankind.

Department of Economics and Sociology.

The Department of Historical Research, which was one of the first to be organized under the auspices of the Institution, has attained an assured position of prominence and approval in the historical world. Under the energetic direction of Prof. Andrew C. McLaughlin, this department has stimulated historical research to a noteworthy degree. The publications issued under his editorship have been widely read by students and by investigators, and the demand for historical papers and documents issued and discovered by the department is constantly increasing. It is with regret that the Executive Committee has been called upon to accept the resignation of Professor McLaughlin, to take effect at the end of the current fiscal year. His report for this year will be found in the Year Book, and attention is invited to the summary he gives of the work of the department up to date. Professor McLaughlin has been succeeded by Prof. J. Franklin Jameson, formerly professor of history in the University of Chicago.

Department of Historical Research.

Work in geophysics has been carried on independently by three investigators, namely, by Prof. Frank D. Adams, at McGill University, Montreal, and by Dr. George F. Becker and Dr. Arthur L. Day, of the U. S. Geological Survey. Briefly characterized, their researches aim to determine the modes of formation and the physical properties of the rocks of the earth's crust. We may confidently expect that the results of these researches will be of great economic as well as of great theoretic importance. The conditions of occurrence of rock constituents and materials, including the precious metals, appear now essentially discoverable by means attainable in the laboratory.

Geophysical Research.

Certain kinds of rocks have already been made artificially, and the making of others is only a question of time and the application of

available resources. Publications already issued and in press from this department of work are furnishing remarkable contributions to our knowledge of the properties of matter, alike of interest and value to the theoretical physicist and to the practical engineer.

Investigations on Nutrition.

Some degree of novelty, it may be said, attaches to the investigations into the physics and chemistry of human nutrition carried on by Prof. F. G. Benedict at Wesleyan University, Middletown, Connecticut; by Profs. R. M. Chittenden and L. B. Mendel, at Yale University, New Haven, Connecticut, and by Dr. T. B. Osborne, of the Connecticut Agricultural Experiment Station, at New Haven, Connecticut. The details of these investigations are far too numerous and technical to permit adequate description here. Summarily, however, it may suffice to state that Professor Benedict is making experiments on men similar to the experiments made by mechanical engineers on steam engines and power plants to determine their physical properties and efficiencies. An apparatus has been devised whereby man as an engine, or power plant, may be studied as carefully and as conclusively as any other mechanical plant. An account of this apparatus and of the results to be expected from its use will soon appear as No. 42 of the publications of the Institution. Professors Chittenden and Mendel, on the other hand, are studying the chemical and physiological processes and effects in man arising from the qualities and quantities of foods he consumes; while Dr. Osborne is engaged in an exhaustive determination of the chemical properties of that large group of foodstuffs known as proteids. The prospective value of these researches admits of no doubt; and in addition to their direct bearing on the human economy, in health and disease, they possess a peculiar interest arising from the fact that the instruments of investigation are also the objects of research.

The Solar Observatory.

Of the larger projects undertaken by the Institution the Solar Observatory ranks first in order of cost for initial construction and equipment. This cost, however, is no more than commensurate with the magnitude of the problem attacked, namely, that of the physical constitution of the sun and his rôle in the solar and stellar systems of the visible universe. The work of construction and equipment of the observatory has been pushed forward with great energy and efficiency during the year, so that the establishment may be expected

to be nearly if not quite complete by the end of another year. Through the courtesy of the University of Chicago, the Snow telescope of the Yerkes Observatory has been mounted and been in constant use at the Solar Observatory during the past summer. This 3-foot reflecting telescope has already furnished excellent results and justifies the sanguine expectations entertained with regard to the 5-foot reflector now nearing completion. The unusually favorable atmospheric conditions which prevail day and night at the site of the observatory have attracted the attention of astronomers and astrophysicists generally. During the past summer a party under the direction of Prof. S. P. Langley, Secretary of the Smithsonian Institution, has been there observing data for the solar constant; while Prof. E. E. Barnard, of the University of Chicago, has utilized the peculiar facilities of the site by installing the Bruce telescope of the Yerkes Observatory and extending his remarkable photographic charts of the Milky Way.

Department of Terrestrial Magnetism.

Not very remotely allied to the work of the Solar Observatory is the work of the Department of Terrestrial Magnetism, though the utility of the latter is perhaps more apparent than the utility of the former. All of the sciences, however, like the phenomena of nature, are more or less interrelated, and this is especially the case with solar and terrestrial physics. There is no doubt, at any rate, that solar activity and terrestrial magnetism are in some degree related. Since the publication of the investigations on terrestrial magnetism by the illustrious Gauss, during the first half of the nineteenth century, comparatively little progress has been made in either theory or practice until within the past decade. It is but just to remark that the recent fruitful renewal of activity in this line of work is due chiefly to the enterprise and energy of Dr. L. A. Bauer, in charge of the Department of Terrestrial Magnetism. The execution of the plan he has outlined for a magnetic survey of the oceanic areas, as well as of the land areas, can not fail to secure data of signal value alike to marine transportation and to magnetic theory. By means of specially devised instruments and apparatus, as explained in Dr. Bauer's report, the department has demonstrated the practicability of making magnetic measurements on a moving ship, and the brig *Galilee*, chartered at San Francisco and refitted for this special purpose, is now engaged on such a survey in the North Pacific Ocean. Considering that the oceanic areas are in the aggregate about three times the aggregate of the

continental areas, it is seen that the fulfillment of the plan contemplated will add greatly to our knowledge of the actual distribution of terrestrial magnetism, even if it should not immediately elucidate this obscure phenomenon.

Minor Projects.

Separate mention of the large number of investigations carried on by the aid of small grants would require undue space here. It will be seen from the list on page 19 that there were sixty-four such grants subject to payment during the year. Many more than this number of investigations, however, were under way, while a few grantees of the year have been unable to begin their projects. A number of researches undertaken by aid of grants made in previous years have been completed and offered for publication. Some of these have been issued during the year and several of them are now in press. It should be stated also that numerous preliminary papers resulting from researches under way have appeared in the current journals. A list of these, obtained by aid of the authors themselves, will be found on pages 43–50.

Specially worthy of mention among the minor projects are the following, by reason of contributions already published or soon to be ready for publication, namely:

1. The archeological and geological researches of Prof. Raphael Pumpelly in Turkestan. The first volume of a report on these researches has been issued during the year and a second is in preparation. Professor Pumpelly had planned to resume field work in Turkestan during the past summer, but the Russian government declined to permit him to return there at this time.

2. The preparation by Prof. Lewis Boss of a fundamental catalogue giving the precise positions of about six thousand stars, embracing all stars from the brightest down to the sixth magnitude. This will make a solid contribution to stellar astronomy.

3. The researches on the moon by Prof. Simon Newcomb.

4. The precise quantitative investigations of Prof. A. A. Noyes and T. W. Richards in chemistry.

5. The comprehensive researches in geology and cosmology by Prof. T. C. Chamberlin, whose preliminary papers have already proved full of interest and suggestion to a wide circle of readers.

6. The work of Prof. Carl Barus on the nucleation of dust-free atmosphere; of Prof. E W. Scripture on researches in phonetics; of Prof. G. R. Wieland on American cycads, and the work of Mr. W. L. Tower on the evolution of beetles, all of which are now in press.

One of the most pressing demands that fell to the President immediately after assuming the duties of his office was that of devising a mode of distribution of the publications of the Institution. Accordingly, at the meeting of the Executive Committee held January 9, 1905, the following tentative rules were submitted and adopted :

Publications and Their Distribution.

1. That, unless otherwise ordered by the Executive Committee, the edition of the publications of the Carnegie Institution of Washington be 1,000.

2. That, unless otherwise ordered by the Executive Committee, the publications be distributed as follows: (*a*) to the Founder and Trustees of the Institution; (*b*) to the leading public libraries of the world; (*c*) to a few of the principal journals which give space to critical reviews of current scientific progress.

3. That, subject to approval by the President, authors of publications of the Institution be permitted to designate a list of 100 persons to whom copies of said publications may be sent free of charge.

4. That authors be furnished free of charge with 25 copies of their contributions published by the Institution.

5 That the President have authority to distribute not to exceed 100 copies of each publication of the Institution, if in his discretion it may seem advantageous to do so.

6. That copies of publications not otherwise provided for be offered for sale at a price sufficient to cover the cost of presswork, paper, and binding, plus an addition of 10 per cent.

Soon after the adoption of this basis for action, a list of the principal libraries and institutions of the world contemplated under rule 2 was compiled, and having been approved by the Executive Committee the work of distribution rapidly followed.

The plan thus adopted has worked without serious embarrassment up to date, but it promises to become inadequate to meet the demands for gratuitous distribution to the less important libraries and to the great number of individuals who may be designated as bibliophiles rather than as users of books. Concerning this matter, some suggestions will be found in a later section of this report.

Great pains have been taken to secure a high quality of paper and first-class presswork for the publications of the Institution. This has proved no easy task, since it has been essential to deal with many authors and firms whose desires, standards, and judgments are often found in conflict with what appears to be for the best interests of the work from the Institution's point of view. Thus some lack of obviously desirable uniformity in paper, presswork, and binding has resulted. Certain of these defects have been unavoidable, owing to the fact that some publications had been intrusted wholly to grantees or authors. It is hoped, however, that arrangements will soon be

perfected whereby the desired uniformity and excellence in paper and presswork of the publications of the Institution may be secured.

A list of the twenty volumes published by the Institution during the year will be found on page 42. They aggregate 2,339 octavo pages and 1,450 quarto pages, making a total of 3,789 pages.

SUGGESTIONS CONCERNING PENDING PROBLEMS OF THE INSTITUTION.

Large versus Small Projects.

Rationally considered, the development of a novel institution, like the Carnegie Institution of Washington, can not be expected to proceed without encountering difficulties and dangers. That the mere establishment of such an institution is no easy matter is witnessed by the fact that the Congress of the United States debated the question of founding the Smithsonian Institution for a decade before attaining a definite plan of procedure. Although the Carnegie Institution of Washington has been free in large measure from difficulties in the way of initial organization, it has nevertheless met with other difficulties of a somewhat ominous character. Among these is that of the relative merits of large and small projects and hence large and small grants.

In the absence of experience it might well appear doubtful whether the income of the Institution may be best used in promoting a small number of large projects not likely to be undertaken by other agencies, or whether the income may be best used in promoting a large number of small projects for which the ways and means are already in part available. Strong a priori arguments may be adduced in support of each of these extreme methods of administration of the income, and the Executive Committee has no doubt acted wisely in taking a mean course, testing thus simultaneously, by actual experience, the merits of both methods.

While careful observation and study of these methods during one year only may not justify the recommendation of any radical departure from the course hitherto followed, it seems essential to indicate certain grave objections to the policy of awarding numerous small grants. These objections are:

First, the excessive amount of time and energy required in the consideration of applications for and in the administration of small grants. Thus far the Institution has formally considered about 1,200 applications for such grants and has made awards to about 300 applicants; but the amount of attention given to the consideration of formal applications represents only a part of the time and

labor consumed by the importunities incident to, if not inherent in, the policy in question. Many of the evils of the "spoils system" already confront us. Some applicants file claims; many are impatient for speedy action; and many, as in the case of academic degrees, speak in the possessive case with respect to grants long before they are awarded.

Secondly, the returns from small grants do not seem to justify the outlay, especially since it is applied in many cases to work which would go on as well without aid from the Institution. Probably a more deliberate and searching investigation of the applicant than has hitherto been practicable would insure better results. It is certain, at any rate, that the possession of a laboratory and enthusiasm, along with a bundle of recommendations, should not suffice to qualify an applicant for the arduous work of research.

Thirdly, a graver objection to this system of small grants lies in its tendency to supplant other sources of support for scientific investigation in allied institutions, and especially in colleges and universities. The facts should be known that thus far the Institution has carried on work through aid given to about 270 individuals connected with 89 different institutions. Of these latter, nearly three-fourths are schools, colleges, and universities. Since the normal condition of an educational institution too often borders on poverty, it is only natural that investigators connected with such organizations should look to the Carnegie Institution of Washington for relief. An easy calculation, however, shows that the possible relief from this source is inadequate. Thus, a conservative estimate of the men and women connected with American institutions of learning alone, and capable of making fruitful researches, would include not less than one thousand. The smallest average annual grant that would be effective in such work is $1,000. Hence it is seen that twice the income of the Institution would not begin to meet the demands on it coming from educational institutions alone. Depending unduly on another institution for support tends also, it would appear, not only to dry up the local springs of support, but to sap the independence of educational institutions. That any of them should desire to know how much aid may be expected from the Institution before making up their budgets for an academic year is a matter of serious import. Obviously it is the duty of the Carnegie Institution of Washington to avoid the danger of supplanting, while seeking in part to supplement, the functions of educational institutions.

No similar difficulties or objections have arisen in the administration of the larger projects of the Institution. In the case of these

projects, however, the ways and means are provided by rather than for, and the investigators are chosen by rather than for, the Institution. In short, the Institution is, in this case, enabled to assume and fix responsibility in the conduct of its affairs and to push them energetically; whereas, in the other case, responsibility is divided, energy is generally lacking, and time and money are in constant danger of being frittered away amongst a multitude of minor interests.

Summarily stated, therefore, the indications are that the policy of awarding numerous small grants to self-suggested investigators is destined to break down under the sheer weight of the importunities it entails; that the results to be expected from such grants are meager; and that the award of them, unless narrowly limited and carefully guarded, may work grave injury to educational institutions.

New Projects.

The demands for attention from applicants for small grants have left scant time during the year for the consideration of more important prospective work falling within the scope of the Institution. It has been deemed essential, also, to devote most of this time to the larger projects already under way, with a view to increasing their facilities and insuring their success. Nevertheless, many new projects have been contemplated, and several of these may be formulated for action without undue delay whenever the Institution is ready to consider them.

Two of these projects which merit special attention, by reason of the fact that they have been considered at much length by advisory committees and by the Executive Committee during the past three years, are (1) an astronomical observatory in the southern hemisphere and (2) a laboratory for geophysical research. Referring to Year Books 1 and 2, therefore, for voluminous details with reference to the history of these projects, it is desired here to commend them as worthy of favorable action by the Board of Trustees as soon as the essential funds are available.

With regard to new projects in general it appears fitting here to call attention to the desirability of allotting ample time for the preparation of plans and specifications and to the necessity of allotting ample time for their execution. The inevitable dangers that confront a research institution are dilettanteism and haste for results. Thorough deliberation in preparation and energetic patience in execution are indispensable to the highest success of such projects.

Since the query whether different departments of research are likely to be equally promoted by the Institution is often raised, it seems worth while to remark that it is an obvious duty of the Executive

Committee to select those projects which give the highest expectations of adequate returns. Projects of this kind are generally susceptible of definite specifications as to ways, means, and objects. At present, however, judging from the great inequalities in definiteness of the projects submitted to the Institution, it must be much easier to formulate plans for good work in some sciences than in others. Hence, quite irrespective of personal prepossessions, it seems best, in this case, to follow lines of least resistance, promoting chiefly those departments of research which promise sure returns, while seeking at all times to raise the less highly developed to the level of the more highly developed sciences.

Suggestions on Distribution of Publications.

A difficulty which is likely to beset the Institution in the near future is that of a just and equitable distribution of its publications. Society has only lately emerged from a period when libraries were maintained chiefly for librarians and bookbinders and when every scholar was either his own librarian or a bibliophile. Along with this laissez faire system there grew up also a system of exchanges, especially between learned academies and men of learning; but the number of such academies and individuals was until lately quite small and well within the limits of a possible free distribution or exchange of publications. In recent decades, however, the number of institutions maintaining libraries and the number of individuals desiring access to publications have greatly increased. The needs of individuals, it must be said, have been admirably met in a general way by the facilities afforded in all of the great libraries of the world, so that the worker with books can no longer afford to be his own librarian any more than he can afford to be his own banker. Nevertheless, the demand for a free distribution of books has increased to an extent far surpassing the increase in effective libraries and effective workers with books. This demand has grown to large proportions in the United States especially, partly by reason of the broadcast distribution of public documents.

Questioning the wisdom of an indiscriminate distribution of the publications of the Institution, the provisional rules given on page 27 were drawn along conservative lines. The experience of the year, however, shows that great pressure will soon be brought to bear on the Institution by individuals and by smaller libraries desiring to be placed on the free omnia list. Since drawing up such a list, which embraces about three hundred of the leading libraries of the world, an attempt has been made to prepare various special lists of institu-

tions and individuals to which, respectively, publications in the varied departments concerned might be sent. This attempt has developed certain baffling obstacles. Chief among these is the awkward duty of discriminating between the persons and the institutions which should and those which should not receive books gratis. The officer called upon to decide must necessarily play the rôle frequently of a dispenser of favors, and be thus subject to the charge of favoritism.

The practical questions raised by this matter are, first, Is the work entailed worth what it costs? And, secondly, Does such work advance science? My opinion is that both questions should be answered in the negative; and my suggestion is that a distribution of publications at once practicable, equitable, and effective may be attained by offering all of them for sale except those reserved for free assignment to authors and to the leading libraries of the world. Publications thus distributed would be pretty certain to go where they are needed, and they would thus also stand or fall by reason of their merits or demerits, as the case may be.

Relations of Institution to the Public.

Precisely what relations the Carnegie Institution of Washington should sustain to the public is a question which does not admit a ready answer. Experience alone can disclose a complete reply, since it must evolve with the development of the Institution itself. Clearly, however, it must be regarded as a semi-public organization, somewhat similar to a university. More exactly, it may be likened to a university in which there are no students.

Obviously the Institution ought to sustain close relations with universities, since they are now the chief centers of research; and, within the limits permitted by mutual independence, those relations should be coöperative, to the end that time and effort may be conserved. Similar relations should obtain, likewise, between the Institution and learned societies. But the possible methods of effective coöperation remain, essentially, to be discovered.

Much less obvious, though hardly less essential of provisional definition, are the relations which the Institution should sustain to the larger, non-academic world. One of the favorable signs of the times is seen in the intelligent interest taken in the affairs of the Institution by this larger world. In spite of a widely prevalent tendency to anticipate the marvelous and the spectacular from scientific investigations, and thus to expect too much, if not the impossible, there is manifest a very generally just appreciation of

such work. Hence the commendable eagerness of the modern public to learn the results of recondite researches calls for some sort of coöperation between the Institution and existing media for the dissemination of information, with a view to furnishing such information in a form at once intelligible and trustworthy. This, among many other questions concerning the relations of the Institution to the general public, seems to merit special consideration in the near future.

Attention may be not inappropriately called here to the fact that while the Institution deeply appreciates the interest in its affairs shown by the public, there is no possibility of following more than a small fraction of the suggestion and the advice welcomed from that source, for their abundance is overwhelming and a choice must be made. Out of the chaos of such suggestion and advice and out of the deliberations within the Institution itself, ways and means for growth and achievement will be found. In the meantime there will be a common need for application of the forbearance and the patience so indispensable to the higher forms of research which it is the object of the Institution to promote.

NOVEMBER 11, 1905.

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington.

GENTLEMEN: In compliance with Article V, section 3, and Article VI, section 3, of the by laws of the Carnegie Institution of Washington, the Executive Committee herewith respectfully submits its report for the year 1904–1905.

The Executive Committee organized December 20, 1904, by the election of Mr. Wright as chairman and Mr. Walcott as secretary. The committee began consideration of the various directions and authorizations given by the Board of Trustees at its meeting, December 13, 1904; also of matters recommended by the committee and approved by the Board.

The results of the work of the Institution for the fiscal year 1904–1905 are shown in the President's report.

During the fiscal year the committee held six meetings.

The by-laws provide, Article IV, section 2, that—

"He [the President] shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board."

In addition, the by laws provide, Article VI, section 3:

"The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the chairman of the Board, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year."

The interpretation assumed for the by-laws is that the President shall submit a report of past operations of the fiscal year of the Institution, with his recommendations for the succeeding fiscal year, and that the Executive Committee shall approve the President's report and recommendations and indorse it as their report, or submit a distinct report and recommendations if the committee does not approve of the President's report and recommendations. With this interpretation the committee herewith approves the report of the President and his recommendations as the report and recommendations of the committee.

There is also submitted a cash and a financial statement.

Cash Statement of Aggregate Receipts and Disbursements Since October 31, 1904.

RECEIPTS.

Interest:		
U. S. Steel Corp. bonds	$500,000	
Atch., T. & S. Fe Ry. bonds	4,000	
North'n Pac. Ry. Co. "	4,000	
" " Gt. N. "	2,000	
L. Shore & Mich. S. "	2,000	
Central Pac. 1st "	2,000	
Deposits, U. S. Trust Co.	11,654.92	
" Am. S. & T. Co.	43.67	
		$525,698.59
Sales of Publications:		
Index Medicus	2,563.26	
Year Book	44.75	
Miscellaneous	430.94	
		3,038.95
Refund on Grants:		
Grant No. 229	30	
" " 273	83.33	
" " 220	86.78	
" " 61	.83	
		200.94
Sundries:		
Printing: (300 copies No. 16, U. of P.)		150
Total		529,088.48
Balance from last report to Trustees, Oct. 31, 1904.		469,961.17
		999,049.65

DISBURSEMENTS.

Investments:		
$50,000 Cen'l Pac. 1st bonds		$51,937.50
Grants:		
Large	$269,940.79	
Minor	142,093.91	
Special	7,749.64	
		419,784.34
Publication		22,162.97
Administration:		
Furniture	1,162.55	
Trustees	1,482.57	
Executive Committee	1,874.53	
Advisory Committee	846.33	
Salaries	17,612.35	
Temporary employees	4,358.32	
Insurance and surety	102	
Rent and telephone	3,483.05	
Office supplies and stationery	1,453.63	
Postage, express, telegrams, and exchange	2,013.85	
Printing (including Year Book)	2,324.74	
Auditor	150	
Sundries	5	
		36,868.92
Total		530,753 73
Cash in Banks:		
U. S. Trust Co., N. Y.	460,619.88	
Nat'l City Bank, N. Y.	3,351.85	
Am. Sec. & T. Co., W., D. C	4,324.19	
		468,295.92
		999,049.65

Financial Statement.

		Assets.	Liabilities.
Endowment			$10,000,000.00
Reserve fund and accrued interest			270,375.00
Bonds (original cost):			
U. S. Steel Corporation bonds, 5 %		$10,000,000.00	
$100,000 Atch., T. & S. Fe Ry. Co. bonds, 4 %		100,112.50	
$100,000 Northern Pacific Ry. Co. bonds, 4 %		101,800.00	
$50,000 Northern Pacific-Great North. 4 % joint bonds		46,500.00	
$50,000 Lake Shore & Michigan South., 4 % L. bonds.		48,222.22	
$50,000 Central Pacific first bonds, 4 %.		51,937.50	
Real Estate and Equipment:			
Furniture		4,342.24	
Station for Experimental Evolution:			
Construction (bldgs., grounds, &c.)	$21,347.31		
Equipment, apparatus, &c	1,854.50		
		23,201.81	
Tortugas Marine Biological Laboratory:			
Construction (bldgs., grounds, &c.)	5,306.13		
Equipment, apparatus, &c.	1,768.35		
Yacht and tender	6,533.00		
		13,607.48	
Desert Botanical Laboratory:			
Construction (building)	4,101.55		
Equipment, apparatus, &c.	2,008.81		
		6,110.36	
Property investment (aggregate cost)			47,261.89
Grants:			
Large			87,332.23
Minor and research assistants			90,830.54
Publication			85,307.68
Administration			31,476.67
Cash		468,295.92	
Unappropriated fund			251,546.02
		10,864,130.03	10,864,130.03

I hereby certify that I have audited the accounts of the Carnegie Institution of Washington, covering the year ending October 31, 1905, and found the above statement correct and true to the best of my knowledge and belief.

J. E. BATES, *Public Accountant and Auditor.*

CARROLL D. WRIGHT, *Chairman*,
CHARLES D. WALCOTT, *Secretary*,
JOHN S. BILLINGS,
DANIEL C. GILMAN,
S. WEIR MITCHELL,
ELIHU ROOT,
ROBERT S. WOODWARD,
Executive Committee.

WASHINGTON, D. C., *November, 1905.*

RESEARCH ASSISTANTS.

The policy in relation to research assistants, as outlined in Year Book No. 2, pp. xlvii–xlviii, was continued, and the persons named below pursued investigations during the year, or for a portion of the year, in the branches of science indicated. The total amount allotted to date for each investigation is appended.

ACREE, SOLOMON F., Johns Hopkins University, Baltimore, Md. Grant No. 204. Studies of pinacone-pinacolin rearrangement and of urazales, at Johns Hopkins University.......... $1,000

ALLEN, CHARLES E., University of Wisconsin, Madison, Wis. Grant No. 159. Studies of homologies of the gametophyte and sporophyte, etc., at Bonn University, under Prof. Strasburger.......... 1,000

BLAKESLEE, ALBERT F., Botanisches Institut, Halle, Germany. Grant No. 160. Investigation of sexuality in lower fungi at German universities.......... 1,000

COBLENTZ, WILLIAM W., Bureau of Standards, Washington, D. C. Grants Nos. 77 and 198. Investigation of the infra-red emission and absorption spectra.......... 2,000

DEAN, ARTHUR L., Yale University, New Haven, Conn. Grant No. 161. Investigating the proteolytic enzymes of plants.......... 1,000

DOUGHTY, HOWARD W., 1024 St. Paul Street, Baltimore, Md. Grant No. 174. Continuation of work on camphoric acid, conducted by Prof. W. A. Noyes.......... 1,000

FARRAR, CLARENCE B., Sheppard and Enoch Pratt Hospital, Baltimore, Md. Grant No. 163. Experimental studies on structure and functions of the cerebral cortex, its histopathology and physiological psychology.......... 1,000

FRANZ, SHEPHARD I., Hanover, N. H. Grant No. 80. Functions of the cerebrum with special reference to the functions of the association areas.......... 1,000

GRIFFIN, LAWRENCE E., Missouri Valley College, Marshall, Mo. Grant No. 81. Expenses of a trip to the Philippine Islands in order to secure material for a study of the embryology, histology, and physiology of the Nautilus.......... 1,000

JOHNSON, ROSWELL H., State Normal School, Cheney, Wash. Grant No. 274. Assistant with Dr. C. B. Davenport at Cold Spring Harbor Laboratory.......... 1,000

JONES, WILLIAM, American Museum of Natural History, New York, N. Y., Grants Nos. 173 and 283. Religion of central group of Algonkin Indians.......... 2,000

KING, ARTHUR S., University of California, Berkeley, Cal. Grant No. 164. Production and study of emission spectra at high temperature, in the universities of Bonn and Berlin.......... 1,000

LEVENE, PHŒBUS A., Ward's Island, N. Y. Grant No. 165. Research along the line of determining points in the constitution of proteids, under the direction of Prof. R. H. Chittenden.......... 1,000

LILLIE, RALPH S., University of Nebraska, Lincoln, Nebr. Grant No. 166. Physiology of protoplasmic movements; study carried on at Woods Hole during summer and rest of the year at Naples.......... 1,000

LOUDERBACK, GEORGE D., Reno, Nev. Grants Nos. 66 and 167. Basin Range structure and glaucophane and associated schists of California and Nevada.......... 2,300

LUTZ, FRANK E., Cold Spring Harbor, Long Island, N. Y. Grants Nos. 142 and 256. Quantitative study of organic evolution, as assistant in Cold Spring Harbor Laboratory, with Dr. C. B. Davenport.......... 2,000

MORSE, ALBERT P., Wellesley, Mass. Grants Nos. 84 and 284. Research on North American Acridiidæ, with especial reference to biology, distribution, and variation $2,000

* OLIVE, EDGAR W., University of Wisconsin, Madison, Wis. Grants Nos. 32, 132, and 271. Researches of minute structure of Acrasicæ and other low forms of plant life 3,000

† PHILLIPS, ULRICH B., Madison, Wis. Grants Nos. 193 and 289. For a study of the history of plantation slave-holdings in the ante-bellum South 600

ROSS, FRANK E., Washington, D. C. Assistant to Prof. Newcomb in his work on the motion of the moon. Without emolument.

RUSSELL, HENRY N., Cambridge Observatory, Cambridge, England. Grants Nos. 88 and 207. Determination of stellar parallaxes by photographs 2,000

SARGENT, PORTER E., 105 Lexington avenue, Cambridge, Mass. Grant No. 175. Investigations in comparative neurology 1,000

SCOTT, GEORGE W., Cosmos Club, Washington, D. C. Grants Nos. 60, 141, and 275. The history and law of private pecuniary claims against the state (principally foreign nations to which the United States has been a party) 3,900

SHEPHERD, ERNEST S., Cornell University, Ithaca, N.Y. Grant No. 176. Systematic study of alloys, with especial reference to bronzes and brasses 750

—— GEORGE H., Cold Spring Harbor, Long Island, N. Y. Grants Nos. 143 and 257. Investigation of heredity, hybridization, variation, mutation, etc., in their bearing upon the evolution of plants, with Dr. C. B. Davenport at Cold Spring Harbor Laboratory 2,000

SILL, HERBERT F. *See* ZERBAN, F.

SMITH, Mrs. MARY R., Palo Alto, Cal. Grant No. 194. Investigation of history and social conditions of the Chinese immigrant in California 1,000

STEVENS, NETTIE M., Bryn Mawr College, Bryn Mawr, Pa. Grant No. 177. Investigation of problems relating to sex determination 1,000

WHITEHEAD, JOHN B., Johns Hopkins University, Baltimore, Md. Grants Nos. 59, 178, and 270. Magnetic effect of electric displacement 3,600

WILCZYNSKI, E. J., Bergstrasse, 25, Hamburg, Germany. Grants Nos. 58 and 135. Investigation of ruled surfaces, etc., in connection with the theory of invariants of differential equations 3,000

ZAHM, ALBERT F., Catholic University of America, Washington, D. C. Grant No. 272. Determination of resistance of air to moving bodies 1,000

‡ ZERBAN, FRITZ, College of the City of New York, New York, N. Y. Grants Nos. 169 and 273. Investigation of rare earths. Assistant to Prof. Baskerville 2,000

* Grants 32 and 132 were not designated as "research assistantships."

† Grant No. 289 was not designated as a "research assistantship."

‡ Resigned in April, 1905, Dr. H. F. Sill succeeding him until September, 1905, after which he was reappointed for the unexpired term.

PUBLICATIONS.

The following is a list of the twenty volumes published by the Institution during the year :

Year Book No 3, 1904 Octavo, 309 pages. 6 plates.
No. 4. The Waterlilies : A monograph of the genus Nymphæa. By Henry S. Conard. Quarto, XIII + 279 pages, 82 text figures, 30 plates, including 12 plates colored to life
No. 8 Bibliographic index of North American Fungi. By W. G. Farlow. Octavo, XXXV + 312 pages.
No. 9. Collected mathematical works of George William Hill. Quarto, Vol. I, XVIII — 363 pages.
No. 19. Coloration in Polistes. By Wilhelmine M. Enteman. Octavo, 88 pages, 6 colored plates, 26 text figures.
No. 20. The coral Siderastrea radians. By J. E. Duerden. Quarto, V 134 pages, 11 plates, 13 text figures.
No. 21. Mythology of the Wichita. By G. A. Dorsey. Octavo, VIII - 355 pages.
No. 22. Report on the diplomatic archives of the Department of State, 1789–1840 By A. C. McLaughlin Octavo, 73 pages.
No. 23. Heredity of coat characters in guinea pigs and rabbits. By W. E. Castle. Octavo, 78 pages, 6 plates, 8 text figures.
No. 24. Mutants and hybrids of the Oenotheras. By D. T. MacDougal, assisted by A. M. Vail, G. H. Shull, and J. K. Small. Octavo, 57 pages, 22 plates.
No. 25. Evolution, racial and habitudinal. By J. T. Gulick. Octavo, XII + 269 pages, 5 plates.
No. 26. Explorations in Turkestan. By Raphael Pumpelly, W. M. Davis, R. W. Pumpelly, and Ellsworth Huntington. Quarto, XII + 324 pages, 6 plates, 174 text figures.
No. 27. Bacteria in relation to plant diseases. By Erwin F. Smith. Quarto, XII + 285 pages, 31 plates, 146 text figures.
No. 28. A revision of the atomic weights of sodium and chlorine. By T. W. Richards and R. C. Wells. Octavo, 70 pages.
No. 29. The color sensitivity of the peripheral retina. By J. W. Baird. Octavo, 80 pages.
No. 30. Stages in the developmenst of Sium cicutæfolium. By G. H. Shull. Octavo, 28 pages, 7 plates, 11 text figures.
No. 31. The isomorphism and thermal properties of the feldspars. Part I, Thermal Study, by Arthur L. Day and E. T. Allen. Part II, Optical Study, by J. P. Iddings. (With an introduction by George F. Becker.) Octavo, 95 pages, 26 plates, 25 text figures.
No. 35. Investigations of infra-red spectra. Part I, Infra-red absorption spectra. Part II, Infra-red emission spectra. By W. W. Coblentz. Octavo, 337 pages, 152 text figures.
No. 36. Studies on spermatogenesis, with especial reference to the "accessory chromosome." By N. M. Stevens. Octavo, 32 pages, 7 plates.
No. 37. Sexual reproduction and the organization of the nucleus in certain mildews. By R. A. Harper. Octavo, 104 pages, 7 plates.

These publications aggregate 2,334 octavo pages and 1,445 quarto pages, making a total of 3,779 pages.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED BY GRANTEES.

Under this heading it is sought to include the titles of all publications bearing upon the work done under grants from the Carnegie Institution of Washington. In the list for the past year, as shown below, there may be some omissions, although it has been the endeavor to make it as complete as possible, and in some cases titles may be included which have only an indirect connection with such work.

ABEL, JOHN J., and TAVEAU, R. DE M., Johns Hopkins Medical School, Baltimore, Md. On the decomposition products of epinephrin. (American Medicine, v. 8, pp. 934-935. Nov. 26, 1904.)

ACREE, S. F., Johns Hopkins University, Baltimore, Md. On the pinacone-pinacolin rearrangement, I. (American Chemical Journal. Feb., 1905.)

———. On the constitution of phenylurazole, III (American Chemical Journal. To appear in March, 1906.)

ALLEN, CHARLES E., Madison, Wis. Das Verhalten der Kernsubstanzen während der Synapsis in den Pollenmutterzellen von *Lilium canadense*. (Jahrbücher für wissenschaftliche Botanik. July, 1905.)

———. Die Keimung der Zygote bei Coleochaete (Berichte der Deutschen Botanischen Gesellschaft. Sept., 1905.)

ALLEN, E. T., and WHITE, W. P., U. S. Geological Survey, Washington, D. C. On polymorphic forms of calcium metasilicate. (American Journal of Science. 1905.)

AMES, JOSEPH S., Johns Hopkins University, Baltimore, Md. Redetermination of Rowland's standard wave-lengths. (Presented before Oxford Conference of Astrophysicists Sept. 25, 1905.)

ANDREWS, CHARLES M., Bryn Mawr College, Bryn Mawr, Pa. Materials in British archives for American colonial history. (American Historical Review, v. 10, pp. 325-349. Jan., 1905.)

BARNETT, S. J., Tulane University, New Orleans, La. Note on Dr. H. A. Wilson's memoir "On the electric effect of rotating a dielectric in a magnetic field." (Proc. Royal Society of London, Series A. June 8, 1905.)

BARUS, CARL, Brown University, Providence, R. I. Note on the variation of sizes of nuclei with the intensity of the ionization. (Science, n. s., v. 21, pp. 275-276. Feb. 17, 1905.)

———. Penetrating radiation associated with the X-rays. (Science, n. s., v. 21, pp. 561-566. April 14, 1905.)

———. On groups of efficient nuclei in dust-free air. (American Journal of Science, v. 20, p. 297. Oct., 1905.)

Properties and distribution of nuclei. (Trans. International Congress of Radiology and Ionization, Liège, Belgium. Sept. 12-14, 1905.)

———. Alternations of large and small coronas. (American Journal of Science, v. 19, pp. 349-356. 1905.)

———. Preliminary results, etc. (American Journal of Science, v. 19, pp. 175-184. 1905.)

BASKERVILLE, CHARLES, and LOCKHART, L. B., College of the City of New York, N. Y. The action of radium emanations on minerals and gems. (American Journal of Science, v. 20. Aug., 1905.)

———. The phosphorescence of zinc sulphide through the influence of condensed gases obtained by heating rare-earth minerals. (American Journal of Science, v. 20. Aug., 1905.)

——— and ZERBAN, F. Inactive thorium. (Journal American Chemical Society, v. 26, p. 1642. Dec., 1904.)

BASSETT, H. P. *See* JONES, H. C.

BAUER, L. A., U. S. Coast and Geodetic Survey, Washington, D. C. The physical decomposition of the earth's permanent magnetic field, No. IV: (*a*) Introductory note; (*b*) Secular motion of a free magnetic needle; (*c*) Vertical earth-air electric currents; (*d*) Residual magnetic field and diurnal variation field. 3 figs (Terr. Mag., v. 9, pp. 113–133. Sept., 1904.)

———. The physical decomposition of the earth's permanent magnetic field, No. V: Systems of magnetic forces causing the secular variation of the uniform portion of the earth's magnetism. (Terr. Mag., v. 9, pp. 173–186. Dec., 1904.)

———. Proposed magnetic and electric observations during the total solar eclipse of August 30, 1905. (Preliminary information.) (Science, n. s., v. 22, p. 216. Aug. 18, 1905)

———. Recent advances in the analysis of the earth's permanent magnetic field. Address before the Int. Elec. Congress, St. Louis, 1904. (Science, n. s., v. 20, p. 634. Nov. 11, 1904.)

———. Magnetic storm of Oct. 31–Nov. 1, 1903, recorded at the Coast and Geodetic Survey magnetic observatories. Illus. (Terr. Mag., v. 9, pp. 25–28. March, 1904.)

———. Results of magnetic observations made by the Coast and Geodetic Survey between July 1, 1903, and June 30, 1904. (App. 3, Rep. 1904, U. S. Coast and Geod. Surv., pp. 185–255, pl 2.)

———. Appeal for coöperation in magnetic and allied observations during total solar eclipse of Aug. 29–30, 1905. (Terr. Mag., v. 9, p. 134. Sept., 1904.)

———. A contemplated magnetic survey of the North Pacific Ocean by the Carnegie Institution. (Science, n. s., v. 21, pp. 594–596. Apr. 14, 1905.)

———. Inauguration of the magnetic survey of the Pacific Ocean and the recent eclipse magnetic observations. Illus. (Terr. Mag., v. 10, pp. 143–145. Sept., 1905.)

———. Department of International Research in Terrestrial Magnetism. With portrait of Andrew Carnegie. (Terr. Mag., v. 9, pp. 1–8. March, 1904.)

———. Note on work of Department of International Research in Terrestrial Magnetism for 1904. (Terr. Mag., v. 9, pp. 88–89. June, 1904.)

———. Work of the Department of Terrestrial Magnetism of the Carnegie Institution for 1905. (Terr. Mag., v. 10, pp. 103–105. June, 1905.)

———. Report of the Department of International Research in Terrestrial Magnetism. (Year Book No. 3, Car. Inst. of Wash., pp. 68-74. 1904.)

——— and LITTLEHALES, G. W. Proposed magnetic survey of the North Pacific Ocean by the Carnegie Institution. (Terr. Mag., v. 9, pp. 163–166. Dec., 1904.)

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———. Earthquake disturbances recorded on the magnetographs at the observatories of the U S. Coast and Geodetic Survey. No. 1. Illus. (Terr. Mag., v. 10, pp. 113–125. Sept., 1905.)

———. Specific electrical conductivity of the air at sea. Illus. (Terr. Mag., v. 10, pp. 126–129. Sept., 1905.)

———. Induzierte Thoriumaktivität in Göttingen. (Reprint from Physikalische Zeitschrift, 6 Jahrgang, no. 14, pp. 436–438. 1905.)

CADY, W. G., Wesleyan University, Middletown, Conn. A direct-recording magnetic variometer. 2 figs. (Terr. Mag., v. 9, pp. 69–80. June, 1904.)

CANNON, W. A., Tucson, Ariz. A new method of measuring the transpiration of plants in place. (Bull. Torr. Bot. Club, v. 32. 1905.)

———. The transpiration of *Fouquieria splendens*. 7 figs. (Bull. Torr. Bot. Club, v. 32, pp. 397–414. 1905.)

———. The biological relations of certain cacti. (American Naturalist. 1905.)

———. On the water-conducting system of some desert plants. 10 figs. (Bot. Gaz., v. 39, pp. 397–408. 1905.)

CASE, E. C., State Normal School, Milwaukee, Wis. *Bathygnathus borealis*, Leidy, and the Permian of Prince Edwards Island. (Science, n. s., v. 22, pp. 52–53. July 14, 1905.)

CASTLE, W. E., Cambridge, Mass. Recent discoveries in heredity and their bearing on animal breeding. (Pop. Science Monthly, pp. 193–208. 14 figs. July, 1905. Proceedings Am. Breeders' Ass , v. 1, pp. 120–126. Sept., 1905.)

———. The mutation theory of organic evolution from the standpoint of animal breeding. (Science, n. s., v. 21, pp. 521-525. April 7, 1905.)

CHILD, CLEMENT D., Colgate University, Hamilton, N. Y. The electric arc in a vacuum. (Physical Review, v. 20, p. 364. June, 1905.)

COBLENTZ, WILLIAM W., Bureau of Standards, Washington, D. C. I. Infra-red emission spectra of metals. II. Infra-red emission spectra of gases in vacuum tubes. (Physical Review, v. 20. Feb., 1905.)

———. Water of constitution and of crystallization. (Physical Review, v. 20. April, 1905.)

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CONE, L. H. *See* GOMBERG, M.

COVILLE, FREDERICK V., U. S. Department of Agriculture, Washington, D. C. Desert plants as a source of drinking water. 2 pl. (Smithsonian Institution Report for 1903, pp. 499–505. 1904.)

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· and HUBBARD, MARIAN E. Studies in the evolution of Pecten. IV. Ray variability in *Pecten varius*. (Journal of Experimental Zoölogy, v. 1, pp. 607–616. Dec., 1904.)

DAVIS, HERMAN S , Dover, Delaware. Flamsteed and Piazzi identities: notes on the nomenclature of some Piazzi stars. (Pop. Astronomy, v. 13. October, 1905)

———. Secular variation of precession from Besselian star constants. (Astronomische Nachrichten, v. 166, p. 73. Aug. 31, 1904.)

DEAN, ARTHUR L., New Haven, Conn. On proteolytic enzymes, I. (Botanical Gazette. May, 1905.)

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DICKSON, LEONARD E., University of Chicago, Chicago, Ill. On the real elements of certain classes of geometrical configurations. (Annals of Mathematics, v. 6, pp 14·–150. July, 1905.)

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———. Determination of all the subgroups of the three highest powers of p in the group G of all m-ary linear homogeneous transformations modulo p. (Quarterly Journal of Mathematics, v. 36, pp. 373–384. May, 1905.)

———. A general theorem on algebraic numbers. (Bulletin American Mathematical Society, v. 11, pp. 482–486. June, 1905.)

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——— On hypercomplex number systems. (Transactions of the American Mathematical Society, v. 6, pp. 344–348. July, 1905.)

———. Definitions of a group and a field by independent postulates. (Transactions Amer Math. Society, v. 6, pp. 198–204. April, 1905.)

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ELSTER, J., and GEITEL, H., Wolfenbüttel, Germany. Vorschläge für die Ausführung electrischer Beobachtungen während der bevorstehenden Sonnenfinsterniss. (Terr. Mag., v. 10, pp. 17–20 March, 1905.)

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HALE, GEORGE E., Mount Wilson, Cal. An expedition for solar research. (Astrophysical Journal, v. 19, p 385. June, 1904.)

HAY, OLIVER P., American Museum of Natural History, New York, N. Y. The fossil turtles of the Bridger basin. (American Geologist, v. 35, pp. 327–342. June, 1905.)

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REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1904–1905, but others on which work has been continued from prior years.

ANTHROPOLOGY.

Dorsey, George A., Field Columbian Museum, Chicago, Illinois. Grant No. 228. *Investigation among the tribes of the Caddoan stock.* (For previous reports see Year Book No. 2, p. xv, and Year Book No. 3, p. 83.) $3,000.

Abstract of Report.—The work done in investigating the tribes of the Caddoan stock is the third of a plan for four years of consecutive and systematic investigation. The investigation of the mythology of the tribes will be completed this year, and there will be available in print the mythology of the Skidi Pawnee, the Pawnee in general, the Caddo, the Wichita, and the Arikara. Observations on many additional ceremonies have been made, and a large number of new rituals have been obtained, together with much additional information about rituals and ceremonies previously observed.

Jones, William, American Museum of Natural History, New York, New York. Grant No. 283. *Investigation of the religion of the Central Algonkin Indians.* (Continuation of Grant No. 173.) $1,000.

The work of the past year was confined mainly to the Ojibwas, the largest tribe in the Central Algonkin group. The field of the work was among the Ojibwas of the north shore of Lake Superior, on Rainy River, and at various places in northern Minnesota. Myths and traditions were collected and religious ceremonies were observed. In view of the fact that the problem is essentially psychological, an effort was made to obtain as much religious lore as possible in the native language itself. The method serves two purposes: In one it reveals the nature of Ojibwa thought and makes clear the psychological basis of Ojibwa religion; in the other it furnishes a store of linguistic material on a side of the language that is fast falling out of use. Beast fable is the predominating characteristic of Ojibwa myths. The mythology is rich with characters of supernatural attributes, but the system of its philosophy is inconsistent. Of the religious rites and ceremonies, an esoteric society called the Midewiwin was selected for particular study. It stands out in marked relief from all the other observances by virtue mainly of its concern with life after death. Its practices give a definite conception of the belief in a disembodied spirit and foster the hope of immortality in the spirit world. Its priests act as media between individuals and unseen powers, and their intercession is in turn connected with the office of sacrifice. Its ceremonies are conducted with ritual. The results of the work among the Ojibwas will, it is expected, be in manuscript some time during 1906.

ARCHEOLOGY.

American School of Classical Studies at Athens. James R. Wheeler, Chairman of Managing Committee, Columbia University, New York, New York. Grant No. 259. (*a*) *Maintenance of a fellowship in architecture at Athens*, $1,000. (*b*) *Excavation on the site of ancient Corinth and exploration*, $1,500. $2,500.

Abstract of Report.—(*a*) Mr. Gorham Phillips Stevens, M. S., Massachusetts Institute of Technology, has given his entire time to the preparation of a series of drawings of the temple on the Acropolis at Athens, known as the Erechtheum. The drawings are now practically completed and are of very high excellence, attracting much attention at the recent International Archeological Congress in Athens. The school is preparing to issue an exhaustive work on this temple, and the publication of the drawings will form an important part of it. Mr. Stevens has been of great assistance to the commission of architects who have had in charge the recent repairs on the Erechtheum, and has made an exceedingly clever and certain restoration of the design of the east front of the temple, the construction of which had previously not been understood. The management of the school looks with high satisfaction upon the work which he ha accomplished.

(*b*) Owing to the meeting of the International Congress of Archeologists at Athens in the spring, and to unexpected difficulties in regard to dumping privileges, which were made by certain villagers of Old Corinth, the beginning of the season's excavation work has been much delayed. The immediate problem before the excavators, however, is the determination of the limits of the market-place (Agora), the position of which was discovered in last year's campaign. It seems probable that the results of this year's work will be almost entirely of topographical interest. A fuller report will be submitted at a later date.

American School of Classical Studies in Rome. Andrew F. West, Chairman of Managing Committee, Princeton University, Princeton, New Jersey. Grant No. 260. (*a*) *Maintenance of two research fellowships in classical archeology*, $1,600. (*b*) *Publication of results of scientific investigation*, $1,000. $2,600.

The first fellows appointed under the grant did not begin their work in Rome until the autumn of 1905, so that there is nothing as yet to report. The first volume of papers of the school, embodying the results of original scientific research, is in press.

Pumpelly, Raphael, Newport, Rhode Island. Grant No. 229. *Trans-Caspian Archeological Expedition.* (For previous reports see Year Book No. 2, p. xxxiii, and Year Book No. 3, pp. 75–79.) $26,000.

Abstract of Report.—The Executive Committee having decided to postpone the expedition, Professor Pumpelly remained in Europe until July, preparing for publication the results of the observations of the different members of the expedition of 1904. To this end he made a broad study of the prehistoric archeology of Europe and the Mediterranean, both by extensive reading and in the prehistoric museums of Naples, Bologna, Zurich, Vienna, Berlin, Paris, and London. Since returning to America, work on the report has progressed rapidly. It will contain many plates and illustrations, and the greatest appreciation has already been expressed by leading European archeologists relative to the results which it will disclose. It will embrace reports by Dr. Hubert Schmidt, of Berlin, Dr. J. Ulrich Duerst, of Zurich, and Prof. F. A. Gooch, of Yale University.

Ward, William H., 130 Fulton street, New York, New York. Grant No. 131. *Study of oriental art recorded on seals, etc., from western Asia and Egypt.* (For previous reports see Year Book No. 2, p. xvii, and Year Book No. 3, p. 85) $1,500.

Dr. Ward reports that he fully expects to finish the work during the first half of 1906.

The work divides itself into geographical regions and chronological periods, and requires classification accordingly, with divisions and subdivisions, according to the designs, and with the attempt to identify the deities, emblems, and various objects drawn on the cylinders. An attempt has been made to include every possible type and to bring together sufficiently numerous examples of each for the use of scholars. There is now substantially completed the writing and the typewriting of the entire Babylonian period, both archaic and later; also of the Assyrian seals; then of those from the Hittite and Syrian regions; also the entire Persian seals, the Sabean, and a considerable portion of the miscellaneous and unclassifiable cylinders (not a large number). There remain to be studied the Cypriote and the Egyptian. Further than this, the bibliographical and the introductory chapters have been prepared, and there has been written, but not copied, a considerable portion of the concluding chapters, which take up involved topics, such as the study of symbols, the succession of garments, the weapons of war and chase, altars and sacrifices, and animals and plants.

ASTRONOMY.

REPORT OF DIRECTOR OF THE SOLAR OBSERVATORY, MOUNT WILSON, CALIFORNIA *

BY GEORGE E HALE, DIRECTOR.

I have the honor to present my first formal report on the Solar Observatory. In view of the fact that the work of the Expedition for Solar Research from the Yerkes Observatory has been continued by the Solar Observatory, this report covers the entire period of our occupation of Mount Wilson, beginning with February 29, 1904

The circumstances leading up to the establishment of the Solar Observatory have been stated elsewhere † and need not be repeated here. Suffice it to say that a grant of $10,000, made by the Executive Committee of the Carnegie Institution in April, 1904, rendered it possible to bring the Snow telescope of the Yerkes Observatory to Mount Wilson in the summer of 1904. As a study of the atmospheric conditions had given rise to belief that the site would prove a very advantageous one, warranting occupation for a considerable period of time, a lease of a large tract of land on the mountain was at once negotiated. The Carnegie Institution had not then decided to establish an observatory of its own, and the future was therefore uncertain. Accordingly the lease was taken by myself personally, but a new lease has since been executed in the name of the Carnegie Institution. The property belongs to the Pasadena and Mount Wilson Toll-road Company, and I desire to put on record my sense of obligation to the officers and controlling stockholders of this company, Messrs. J. H. Holmes and W. R. Staats, of Pasadena, to whom we are indebted for liberal and courteous treatment. The lease, which comprises a large tract (not yet completely surveyed) of the best land on Mount Wilson, not only involves no charge for the use of the property, but establishes restrictions of great importance on the adjoining land of the toll-road company. These restrictions, as fully set forth in the lease, seem to obviate completely such interference with the observations as might be caused by smoke, electric lights, vibrations from machinery, and other similar disturbances. The lease also contains other advantageous concessions, including one-half the water rights on Mount Wilson, free use of the toll trail to the valley, etc. The seemingly unique advantages of Mount Wilson, in atmosphere, topographical features, and proximity to an

* Grant No. 217. $150,000 for building observatory and maintenance for 1905. (For preliminary report see Year Book No 3, pp. 155–174.)

† Contributions from the Solar Observatory, Nos 1 and 2.

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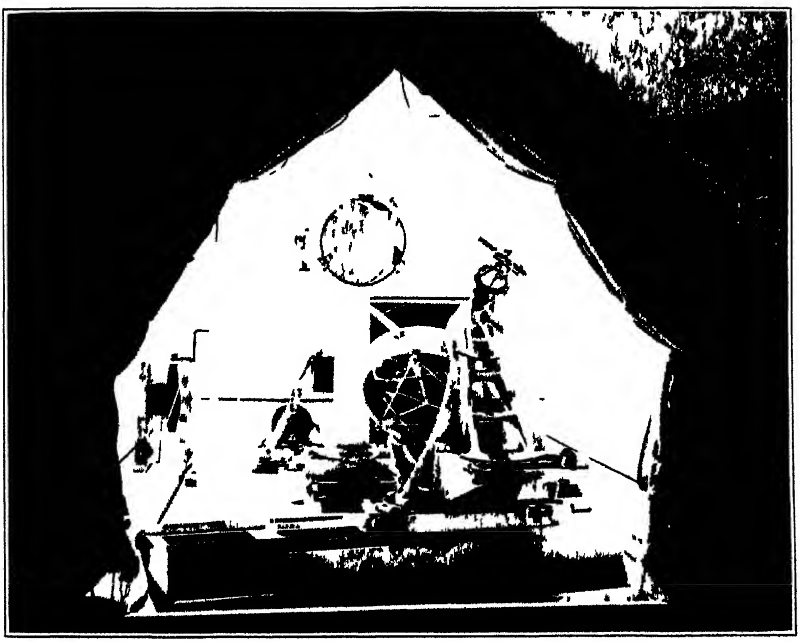
SOUTH END OF SNOW TELESCOPE HOUSE.



COELOSTAT AND SECOND MIRROR OF NEW TELESCOPE.

important base of supplies like Los Angeles, will indicate the value of this lease to the Solar Observatory.

In Contributions from the Solar Observatory No. 1, I have given a detailed account of the systematic tests of the atmospheric conditions at Mount Wilson made prior to January 1, 1905. Since the telescopic tests of this period were necessarily limited to solar observations with a refractor of 3¼ inches aperture, they might perhaps be considered inconclusive, especially as they related entirely to sharpness of definition, and took no account of transparency of the atmosphere. At present, however, any doubts that might have existed on this score have been removed, for extensive tests with powerful instruments have fully confirmed, and even strengthened, the favorable opinion previously entertained. The large aperture and great focal length of the Snow telescope have rendered the tests of the solar definition very severe, and the number of days of fine seeing recorded under such conditions is most gratifying. The transparency and uniformity of the sky by day have been fully proven by Mr. Abbot's precise measures of the solar radiation with the pyrheliometer and spectro-bolometer, and these conditions, with the long stretches of unbroken clear weather, have left no doubt of the advantages to be gained from a continuation on Mount Wilson of the important research instituted here by the Smithsonian Expedition. Professor Barnard's remarkable photographs of the southern Milky Way, including many star clouds and extended nebulæ not previously recorded, and showing numerous stars to exist in regions heretofore supposed to be devoid of stars, testify to the transparency and purity of the night sky, and his systematic tests of the seeing by night have shown it to be very fine. These tests, made with the 5-inch guiding telescope of the Bruce telescope, have been amply confirmed with the large aperture of the Snow telescope. In photographing stellar spectra with the high dispersion of a powerful grating spectroscope, the observer has the star's image constantly under observation for many hours at a time. In this work it has been found that the average night-seeing is exceedingly good, while the low wind-velocity, coupled with the transparency of the atmosphere, afford additional advantages which should render Mount Wilson an ideal site for the 5-foot reflector.

PLAN OF RESEARCH.

Before proceeding to describe the work so far accomplished, it is desirable to call attention to the plan of research prepared for the observatory. This plan has been set forth in Contributions from

the Solar Observatory No. 2, but the developments of the last few months have cleared up some points of uncertainty, especially as regards the desirability of including a systematic study of the solar radiation in our observational program. Furthermore, the question recently raised by the editor of the Popular Science Monthly, as to the wisdom of establishing the Solar Observatory in a State already so well represented by the Lick Observatory, indicates that the purpose of the Solar Observatory is not yet clearly apprehended by some men of science. The Carnegie Institution would certainly run counter to its well-defined principles by duplicating the work of the Lick Observatory, and the Solar Observatory would not accomplish its purpose if this were done.

The purpose of the Solar Observatory may be defined as follows:

(1) The investigation of the sun (*a*) as a typical star, in connection with the study of stellar evolution; (*b*) as the central body of the solar system, with special reference to possible changes in the intensity of its heat radiation, such as might influence the conditions of life upon the earth.

(2) The choice of an effective mode of attack, involving (*a*) the application of new methods in solar research; (*b* the investigation of stellar and nebular phenomena, especially such as are not within the reach of existing instruments; and (*c*) the interpretation of these celestial phenomena by means of laboratory experiments.

(3) The design and construction of a large reflecting telescope and of new types of instruments peculiarly adapted for the purposes in view, with special reference to the possibilities of research through the study of celestial objects under laboratory conditions.*

4) The accomplishment of the foregoing purposes at a site where the atmospheric conditions have been shown to be exceptionally favorable: Mount Wilson (5,886 feet), in southern California (lat. $+34° 13' 26''$, long. W. $118° 3' 40''$).

(5 The furtherance of international coöperation in astrophysical research through the invitation to Mount Wilson, from time to time, of investigators specially qualified to take advantage of the opportunities afforded by the Solar Observatory.

STAFF.

My principal associates on Mount Wilson are Ferdinand Ellerman and Walter S. Adams, assistant astronomers. Mr. Charles S. Backus is a general assistant. At the Pasadena office and instrument shop

* See The Development of a New Observatory, Publications of the Astronomical Society of the Pacific, Vol. XVII, p. 41. 1905.

the work of construction is carried on under the supervision of Prof. G. W. Ritchey, astronomer and superintendent of instrument construction.

Prof. Winslow Upton, Director of the Ladd Observatory of Brown University, and Prof. L. H. Gilmore, of Throop Polytechnic Institute, were engaged in special work at the Solar Observatory during the summer of 1905.

During 1905 the following expeditions have conducted observations on Mount Wilson in coöperation with the Solar Observatory:

Hooker Expedition: Edward E. Barnard, astronomer of the Yerkes Observatory, in charge.

Smithsonian Expedition: Charles G. Abbot, aid acting in charge of the Smithsonian Astrophysical Observatory, in charge; Leonard R. Ingersoll, University of Wisconsin, assistant.

INVESTIGATIONS IN PROGRESS.

Although the program of observations must naturally be a restricted one until the completion of the instrumental equipment, it has nevertheless been possible to commence systematic work in four departments: (1) daily photography of the sun with the photoheliograph; (2) daily photography of the sun with the spectroheliograph; (3) photography of the spectra of sun-spots and flocculi; (4) photography of stellar spectra with a grating spectrograph of high dispersion. Since the Snow telescope has been employed in all of this work, an account of the tests of this instrument should precede a description of the investigations named.

The Snow telescope was set up on Mount Wilson in January, 1905, but the extremely wet weather of the rainy season rendered it inadvisable to put the mirrors in place until about March 15, 1905. On the return of favorable weather, tests of the telescope were at once undertaken. It was found that the heating of the mirrors by the sun produced marked changes of focal length, together with such evidences of astigmatism as would be expected to follow from the distortion of the plane mirrors. The focal distance lengthened rapidly after the mirrors had been exposed to the solar rays for a short time, but soon reached a maximum, where it remained fairly constant. Speaking approximately (as the results varied considerably at different times), the change from normal to maximum, with the mirror of 60 feet focal length, was from 3 inches to 1 foot. It was soon noticed that the change became more marked as the silvered surfaces grew older and more tarnished, on account of the greater absorption of heat. For a time it seemed probable that the use of the telescope

would be seriously handicapped by these changes of focal length, not only because of the poor definition caused by astigmatism, but also because the long exposures required with the spectroheliograph would be impracticable under such conditions. Attention was therefore concentrated on two objects: (1) the provision of a remedy for the difficulty experienced with the mirrors; (2 the reduction of exposure time in the spectroheliograph.

The solar definition at Mount Wilson is best about an hour after sunrise. At this time the mirrors, after being cooled by the night air, might be supposed to give most trouble on account of the rapid change of temperature after sunrise. It was accordingly thought that it might be desirable to maintain the mirrors during the night at a temperature approximating that attained during the day after exposure to the sun. Experiment soon led, however, to a different solution of the problem. At the time of best definition the radiation from the low sun undergoes considerable absorption in the earth's atmosphere. Although this makes necessary an increased exposure in the spectroheliograph, it is nevertheless very advantageous in preventing rapid heating of the mirrors. In fact, if the exposure time is made as short as possible and the mirrors shielded from the sun between exposures by an adjustable canvas screen, the change of focus can be so reduced as to become of small importance during the period of best definition, which lasts about an hour.

The experiment has been tried of cooling the mirrors with a blast of air after they have been exposed for some time to the sun. The good effect of this treatment was shown by a considerable change of focus toward the normal position. Electric fans are accordingly being installed to blow each of the three mirrors while they are exposed to the sun during the adjustment of the spectroheliograph, and between exposures, when the mirrors are also shielded by a canvas screen. The success attained in decreasing the exposure time with the spectroheliograph is described below. The result of the combined efforts was to yield photographs of the sun equal, if not superior, to the best obtained with the 40-inch Yerkes telescope and the Rumford spectroheliograph. When it is remembered that the spectroheliograph employed in the present work is an instrument of the simplest construction, extemporized for use until the permanent spectroheliographs can be completed, it will be seen that such results are to be regarded as satisfactory.

It should be added that photographs of the sun suitable for most classes of work can be made with the Snow telescope at almost any hour of the day. Advantage is taken, however, of the fine definition

soon after sunrise and before sunset to secure the daily record, so that the plates may be suitable for investigations of the more minute solar phenomena.

Images of the stars and of the moon given by the Snow telescope are frequently very fine, but after the mirrors have become distorted through heating by the sun they sometimes do not return to their normal figure for many hours. The images observed at such times are greatly distorted and usually multiple in character.

The special form of house designed for the Snow telescope has proved very satisfactory. The louvres and ventilated roof undoubtedly accomplish their purpose, as the air within the house remains cool even at midday.

QUARTZ MIRRORS.

The above remarks emphasize the importance of carrying to a successful issue the experiments on the use of fused quartz for mirrors undertaken last year and reported upon in Year Book No. 3 (p. 127). Professor Gilmore, of Throop Polytechnic Institute, who has carried on the experiments this year in conjunction with Professor Ritchey, succeeded in making quartz disks decidedly better than any obtained in the earlier work. The method of heating the quartz crystals to about 500° C. before dropping them into the white hot electric furnace proved more successful than other methods, in that the disks thus produced contain fewer bubbles. Nevertheless the bubbles still remaining are too numerous to permit a satisfactory optical surface to be given the quartz disks, and experiments in remelting the surface in the electric arc have not succeeded, as was hoped, in removing the bubbles from a superficial layer of sufficient thickness for figuring. The molten quartz is far too viscous to permit the bubbles to be removed by stirring, but it is hoped that melting the crystals under pressure may accomplish the purpose.

Meanwhile there is reason to hope that materials other than ordinary glass or fused quartz may prove suitable for mirrors. Schott, of Jena, has produced an opal glass having a coefficient of expansion about one-third that of ordinary glass. Other glass-makers will be induced, if possible, to make special experiments in the hope of producing glass of low expansion coefficient.

There is reason to think that speculum metal, on account of its high conductivity of heat, may not undergo in sunlight such surface distortion as glass exhibits. We are preparing similar mirrors of glass and speculum metal for a careful comparative test to decide this question.

DIRECT PHOTOGRAPHY OF THE SUN (MESSRS. HALE AND ELLERMAN).

Photographs of the sun on a scale of 6.7 inches to the solar diameter are taken daily with the Snow telescope. With the present exposing shutter the aperture of the 60-foot mirror must be reduced to about 3 inches when Process plates are used. A separate photoheliograph will be provided later, so that the Snow telescope may be used exclusively for work with the spectroheliograph during the hours of best definition. Many of the direct photographs already obtained are very sharp and have been of great service in comparisons (with the stereocomparator) of faculæ with H_1 photographs of the flocculi.

WORK WITH THE SPECTROHELIOGRAPH (MESSRS. HALE AND ELLERMAN).

The temporary spectroheliograph, built for use with the Snow telescope pending the construction of the 5-foot spectroheliograph, is a simple but very efficient instrument. A heavy wooden base (saturated with melted paraffin to prevent change of shape in moist and dry weather) carries two iron rails of V section. Four steel balls run in these V's and in the inverted V's of two iron rails on the lower side of the wooden platform that bears the slits and optical parts. The first slit, the collimator, and the camera are from the old Kenwood spectroheliograph. The two prisms, of 64° refracting angle, were made for the Bruce spectrograph of the Yerkes Observatory, but had to be replaced in that instrument because of their imperfect definition. This is sufficiently good, however, for spectroheliographic work, where the requirements in this particular are less severe than in stellar spectroscopy. In the absence of a suitable mirror, to give the required deviation of 180°, the silvered face of a third prism is employed. The second slit and plate-holder support belonged to a spectroheliograph of the type suggested by Newall, which was built for experimental purposes at the Yerkes Observatory. The solar image and plate are fixed and the spectroheliograph is moved across them by means of a small electric motor. This is belted to a large wooden pulley on a screw supported by the wooden base and running in a nut attached to the moving platform.

The optical parts in this simple instrument are small, and therefore only a narrow zone of the 6.7-inch solar image can be photographed. For special studies of spot regions and of interesting flocculi, however, no better instrument could be desired. The great advantages of a spectroheliograph mounted on a pier over one attached to an equatorial telescope have made themselves evident from the

first. It has been easy to change the exposure time by the use of a cone pulley on the motor and by the provision of a worm gear for very slow speeds. The convenience of experimentation thus afforded has rendered possible a long series of tests involving considerable variations in slit-width, speed, and plate sensitiveness. These experiments will be completed with the 5-foot spectroheliograph, which offers many additional advantages. It may be said, however, that the most satisfactory results (for H_2) have been obtained with Process plates, high speeds (from 0.2 to 0.3 inch per second), and wide slits. It must not be forgotten, as Newall has pointed out, that very wide slits can not be used without producing an astigmatic effect in the direction of dispersion, unless an even number of reflections (or no reflections) occur in the optical train. The 5-foot spectroheliograph, when used with two prisms, is designed to give either one or two reflections, as desired.

In my discussion of the results obtained with the Rumford spectroheliograph, I adopted a working hypothesis which assumes that photographs taken with the second slit set on the broad dark band H_1 represent the low-lying, dense calcium vapor in the flocculi, while those taken with H_2 show the less dense calcium vapor at a higher level. Mr. Evershed has advanced good arguments in favor of his view that the H_1 photographs represent the faculæ proper, the increased contrast being due to the dark background afforded by the dark band. This assumes that the level of the faculæ is above that of the denser calcium vapor, but photographs of the spectrum of the faculæ taken on Mount Wilson show that the bright band representing their continuous spectrum is greatly reduced in intensity near the middle of H_1 and K_1. The strength of this counter-argument, however, is lessened by the fact that this same evidence conclusively shows the absence of such reversals of H_1 and K_1 as my working hypothesis would seem to require. It is evident that further advance must depend in large measure upon a series of careful comparisons of faculæ near the sun's limb (taken direct or with a spectroheliograph having its second slit set on the continuous spectrum) and of the same objects photographed nearly simultaneously with a spectroheliograph set on H_1.

A Zeiss stereocomparator (not available in the work at the Yerkes Observatory) has afforded the means of comparing photographs with the necessary precision. Numerous plates of the recent large spot groups have supplied excellent material for the tests. Though the comparisons are not yet completed, it may be said that they now seem more favorable to Mr. Evershed's view than to my own. In

continuing the work special care will be taken (1) to obtain photographs with H_1 and with the continuous spectrum without change of slit-width (in the temporary spectroheliograph a change of slit-width has been necessary in order to compensate for the difference in brightness); (2) to increase the contrast in photographs of the faculæ proper, so that the comparisons may be made nearer the center of the disk, as well as near the limb.

Mr. Evershed's alternative view that the H_1 photographs may be due to H_2 light reflected from the slit jaws has been rendered untenable. The beveled edges of the jaws in the temporary spectroheliograph are turned toward the plate, so as to reduce the possibility of reflection; but in any event the differences in form of H_1 and H_2 images are such as to preclude this view.

H_1 photographs undoubtedly represent a lower level than H_2 photographs; there is no question on this point. The doubt is whether H_1 photographs show the faculæ themselves or the calcium vapor in or above the faculæ, and whether the level represented depends upon the position of the second slit on the H_1 band. The Rumford spectroheliograph results formed the basis of my working hypothesis, but in some respects they were less suitable for this purpose than the photographs recently taken on Mount Wilson. Now that the 5-foot spectroheliograph is completed, it should be possible to settle the matter in a short time.

A description of this large instrument is reserved until the completion of the tests now in progress. With its large aperture (8 inches) and focal length (5 feet); the possibility of using a dispersion of from one to four prisms with an odd or even number of reflections; the wide range of speed afforded by the electric driving mechanism; the convenient means provided for focusing on the solar image, setting on the spectral lines, and attaching slits of various curvatures—this spectroheliograph may reasonably be expected to yield results surpassing those hitherto obtained.

A spectroheliograph of 8 inches aperture and 30 feet focal length, with three prisms of 50°, is now under construction. This instrument is designed especially for the photography of limited regions of the solar disk with Fraunhofer lines other than those of calcium and hydrogen, including the lines affected in and near sun-spots.

A method of measuring the heliographic latitude and longitude of points on photographs of the solar disk by projection upon the surface of a ruled globe has been successfully employed by Mr. Fox and myself at the Yerkes Observatory. A modified form of the apparatus, which I have more recently devised, is now under con-

struction in our instrument shop and will soon be mounted in the laboratory on Mount Wilson. It will also be suitable for the measurement of the position angle, height, and heliographic latitude of prominences, as well as for the monocular comparison of two photographs in a manner similar to that employed in the stereocomparator. A measuring machine, recently completed for us by William Gaertner & Co., after the designs of Dr. Frank Schlesinger, furnishes the means of determining rectangular coördinates on solar or stellar photographs, when it is desired to employ the ordinary methods of measurement and reduction. A special micrometer for the stereocomparator, designed for use with a réseau, is also under construction by the Zeiss Company.

SPECTRA OF SUN-SPOTS AND FLOCCULI (MESSRS. HALE AND ADAMS).

The plan of research prepared for the Solar Observatory lays special stress on the simultaneous study of solar phenomena from several points of view. To obtain adequate knowledge of the nature of sun-spots, for example, it is not enough to make direct or monochromatic photographs of the spots, or to devote all our attention to a study of their spectra. Direct photographs are useful in giving the heliographic position and general character of the spots and the details of their structure. They tell nothing, however, of the forms and motions of the invisible vapors surrounding them, or of those peculiarly characteristic vapors within the spots that are represented by the widened lines. To study these forms we must employ spectroheliographs, of moderate dispersion for high and low level photographs with the calcium lines, of great dispersion when it is desired to study the distribution of the rarest and most lofty vapors of calcium or the luminous clouds revealed with the aid of the narrow lines of other substances. In the interpretation of these photographs, however, and for other purposes as well, we must have the assistance of high-dispersion photographs of spectra. The spectroheliograph plates themselves furnish the means of studying the motions of the luminous vapors parallel to the solar surface, but the distortions and displacements of the spectral lines, as determined by the most precise measurements, supply the only available means of measuring the velocities of ascent or descent. For the interpretation of the phenomena of widened lines and for an explanation of the causes which bring about the disappearance or complete reversal of Fraunhofer lines over spots, recourse must be had to such laboratory experiments as are referred to elsewhere in this report.

Finally, to mention only some of the principal modes of attack, without going further into detail, the bolometer or radiometer furnishes the necessary means of measuring the radiation energy of the spots and photosphere in various parts of the spectrum, thus supplementing in an important way the instruments already mentioned. All of these modes of solar observation have been brought into use on Mount Wilson, thanks to the Snow telescope, which supplies the first requisite—a large and well-defined solar image within a laboratory.

The photographs of spectra obtained with this instrument well illustrate its advantages over an equatorial telescope. The long and powerful Littrow spectrograph, having a combined collimator and camera lens of 18 feet focal length, could not possibly be attached to such a telescope as the 40-inch Yerkes refractor. The photographs obtained with this spectrograph are naturally far superior to the best we were able to make with the 40-inch, and the precision with which they can be measured is in proportion to the respective focal lengths of the spectrographs used in the two cases—42 inches at Lake Geneva and 216 inches at Mount Wilson. The third-order spectrum of the same grating (the one formerly used in the Kenwood spectroheliograph) was employed in both cases. A great number of widened lines are shown in the spot spectra and the reversals of H and K are admirably brought out. Systematic work with this instrument has been going on since the latter part of August and will be continued regularly.

Certain conclusions, of importance in their bearing on future work, have resulted from the experiments already made. These are (1) the advantage of using a large solar image, in the present case 6.7 inches in diameter, produced by the mirror of 60 feet focal length; (2) the advantage of very high resolving power and linear dispersion in the spectrograph; (3) the importance of providing for a simultaneous attack on the same solar phenomena with a suitable battery of independent instruments. I have accordingly designed a cœlostat telescope of 60 feet focal length and a powerful spectrograph especially for work on the spectra of sun-spots, flocculi, and the chromosphere, and the study of the solar rotation. It is hoped that this instrument, which is to be erected next year, will combine a high degree of efficiency with moderate cost. A special merit of this telescope lies in the fact that it will set free the Snow telescope for uninterrupted work with the spectroheliograph during the early morning hours of fine definition, and at the same time permit the various spectroscopic phenomena to be simultaneously recorded.

STELLAR SPECTROSCOPY (MESSRS. HALE AND ADAMS).

One of the principal objects of the Solar Observatory is to secure photographs of the spectra of certain bright stars with a long focus grating spectrograph on a scale comparable with that of Rowland's photographs of the solar spectrum. It is hardly necessary to say that such photographs, if sharply defined, would be of the greatest service in an investigation of the physical condition of various types of stars and their relationship with the sun and with one another. On account of the great length and weight of suitable grating spectrographs and their liability to flexure, it is impossible to attach them to equatorial telescopes. Consequently, in the absence of powerful horizontal telescopes, such investigations as that here described have not previously been undertaken.

Evidently the principal difficulty to overcome is the extreme faintness of the star's light as compared with that of the sun. The importance of using a telescope of large aperture is therefore obvious, but in any case the exposure of the photographic plate must be very long. Hence the spectrograph must be rigidly mounted on a heavy pier in a room where the temperature can be kept nearly constant throughout the exposure. If no change occurs in the relative positions of slit, lenses, grating, and plate, and if the grating itself is maintained at a constant temperature within very narrow limits, the spectral lines should occupy precisely the same positions on the plate whenever the star is on the slit. In extreme cases the orbital and diurnal motions of the earth must be taken into account, but these need cause no trouble. Thus the exposure may be prolonged until the feebly luminous image has registered itself on the plate.

The spectrograph used in the work with the Snow telescope has collimating and camera lenses of 5 inches aperture and 13 feet focal length, mounted rigidly, with the slit, grating-mount, and plate-holder, on a single massive stone pier. The large plane grating, for the use of which we are indebted to the kindness of Professor Ames, of Johns Hopkins University, was ruled on Rowland's engine many years ago. Although fairly bright in the first order, the spectra are much less brilliant than those of the best gratings of recent years. However, as no other large grating could be had, we were very glad to be favored with the use of this one. The grating is mounted in the front of a cubical brass box and its rear surface is bathed by water, which is constantly stirred by paddles revolved at slow speed by a small electric motor, supported on the wall of the room. Special precautions are taken to prevent vibration of the grating from the

motor or its connections. A bulb containing saturated ether vapor is immersed in the water, which is heated by two small incandescent lamps controlled through a relay. If the temperature rises too high the current is cut off by the expansion of the ether vapor, which moves a column of mercury and thus breaks contact in the relay circuit. In the preliminary work on Arcturus described below, the grating showed no variations of temperature equal to 0.1° C., as measured by a thermometer immersed in mercury in contact with the grating. Further improvements in this apparatus will undoubtedly give all necessary constancy of temperature.

An automatic arrangement is now being installed to control the temperature of the entire spectrograph, as the variations of several degrees from minimum night to maximum day temperature, which occur in extreme cases, are greater than can be allowed. Under ordinary circumstances the range within the room is very small and probably inappreciable in effect.

One photograph of the blue region of the first-order spectrum of Arcturus required an exposure of fourteen hours on three successive nights. Another, made when the mirrors were badly tarnished, required twenty-four hours on five successive nights. The guiding was done with the aid of electric slow motions attached to the mounting of the 60-foot concave mirror of the Snow telescope, supplemented by cords (kept taut by weights) with which the cell can be sprung slightly without danger of distorting the mirror. The good definition and the uniform succession of clear nights make Mount Wilson an excellent place for such work.

The photographs are good, but they are not equal to solar spectra taken in the same apparatus with short exposure. It is expected that improved temperature control will remedy this difficulty. The value of the spectra is well shown by the fact that the measures of a large number of lines made by Mr. Adams show the linear error of setting to be as small as in the case of the best Bruce spectrograph plates. As the scale of the present photographs is nearly three times as great, the increase of precision should be in the same ratio.

These experiments with the Snow telescope should be of special service in their bearing on the design and use of the large grating spectrograph for the five-foot reflector. As this instrument will give six times as much light as the Snow telescope, it is already evident that valuable results may be expected from its application to high-dispersion stellar spectroscopy.

HOOKER EXPEDITION.

As the result of a special gift made by Mr. John D. Hooker, of Los Angeles, for this purpose, Professor Barnard was enabled to bring the Bruce telescope from the Yerkes Observatory to Mount Wilson in December, 1904, and to carry on photographic work with it until the completion of his program in September, 1905. Although the work is to be considered as that of the Yerkes Observatory, I may be permitted to say a few words regarding it in the present report. Professor Barnard's special object was to photograph the southern part of the Milky Way, in the region that can not be reached from the latitude of Williams Bay. He has accomplished this purpose in a most satisfactory manner, with the same untiring zeal that he has shown in all his undertakings. The perfection of the photographs, testifying at once to the skill of the observer, the excellence of his instruments, and the purity of the sky, must be seen to be appreciated. They include not only the large plates made with the 10-inch Brashear lens, but also three complete series of smaller plates, made with a powerful battery of lenses, all working simultaneously. In addition to his photographic observations in the southern heavens, Professor Barnard has made many valuable plates of northern objects. It is hoped that provision will be made for the early publication of these results, as they constitute a most important contribution to our knowledge of the structure of the Milky Way and of the remarkable nebulæ within it.

SMITHSONIAN EXPEDITION.

The inception of the Solar Observatory was due to a suggestion made by Secretary Langley, of the Smithsonian Institution, regarding the desirability of providing for systematic observations of the solar radiation at a mountain station. The work of the Smithsonian Observatory during the last few years has emphasized this suggestion by indicating the probability that the solar constant has undergone considerable variations. Furthermore, these variations nearly coincide in time with apparent changes in the absorbing power of the solar atmosphere and in the mean temperature of the earth's atmosphere. So important a conclusion deserves the most complete investigation, such as might result from a simultaneous attack with similar apparatus from Washington and Mount Wilson. As Mr. Langley had planned to send an expedition to some mountain station for this purpose, it was a special pleasure to place at his disposal all the facilities that could be offered by the Solar Observatory. He

accordingly decided to send an expedition to Mount Wilson under his own direction and under the auspices of the Smithsonian Institution. Mr. C. G. Abbot, aid acting in charge of the Smithsonian Astrophysical Observatory, was placed at the head of the party, and Mr. Leonard R. Ingersoll, of the University of Wisconsin, came as his assistant. The usual work at Washington is being continued by Mr. Fowle. Although conducted under the auspices of the Smithsonian Institution, the work of this expedition bears so important a relationship to that of the Solar Observatory that a brief statement regarding it may not be inappropriate.

As is well known, the direct measurement of the solar radiation received at the surface of the earth is much less difficult than the determination of the amount of heat lost by absorption in our atmosphere. Although it has attacked both phases of the subject in a most thorough manner, the Smithsonian Observatory enjoys special distinction from the fact that the bolometer used there permits the relative amount of the atmospheric absorption to be automatically recorded for each wave-length of the spectrum. In short, it furnishes the information essential in determining the true value of the solar constant.

The fine weather experienced by the Smithsonian party since the installation of their instruments on Mount Wilson has permitted a great amount of excellent work to be done. The collection of bolographs and pyrheliometer readings is so great that months will be required for their complete discussion. In addition to all of these observations, much time has been devoted to frequent determinations of the absorption in the apparatus, experimental work with a new and promising form of recording pyrheliometer devised by Mr. Abbot, and bolographic observations of the radiation of sun-spots and the absorption of the solar atmosphere, made with the 6.7-inch image given by the Snow telescope. As all the results indicate that Mount Wilson is an ideal site for investigations of the solar radiation, Secretary Langley has been invited by President Woodward to continue the work of the expedition, at least during another summer. If for any reason he shall not be able to accede to this request, arrangements will be made for the Solar Observatory to carry forward the observations in coöperation, it is hoped, with the work of the Smithsonian Astrophysical Observatory in Washington. The Solar Observatory has profited greatly by the visit of Messrs. Abbot and Ingersoll, and all the members of the staff would be glad to see it repeated another year.

BUILDINGS AND EQUIPMENT ON MOUNT WILSON.

In the present report it is unnecessary to refer at length to the design and construction of buildings, as they will be fully described in other publications. For the sake of completeness, however, a brief account will be given of the work of construction hitherto accomplished.

Temporary Building for 15-inch Cœlostat Telescope.—This inexpensive structure was erected in the spring of 1904 and served admirably for the experiments with the small cœlostat and 6-inch objective of 60-foot focal length brought out from the Yerkes Observatory. This work was of special value in determining the design of the permanent building for the Snow telescope.

The "Casino."—An old log cabin, used many years ago for the entertainment of visitors at Strain's Camp, now belonging to the Pasadena and Mount Wilson Toll-road Company, was made habitable and occupied until December, 1904, by the members of the staff on Mount Wilson. It was also used during all last season and a part of this for the workmen's mess.

Snow Telescope Building.—This building has been described in Contributions from the Solar Observatory No. 2. It was completed in the summer of 1905, including all electric wiring, plumbing for dark-rooms, fire protection, etc. The framework is of steel and the canvas covering, chosen because it heats but little in the sun, is painted with fireproof paint, found by our tests to be very effective. As stated elsewhere in this report, the louvres and roof ventilation of this building have answered their purpose admirably.

Mount Wilson Shop and Power-house.—This building, described in No. 2 of the "Contributions," contains the gasoline engine, dynamo, and switchboard of the electric plant, as well as the tools needed for work of construction and repair on the mountain. The storage battery of thirty cells, installed here temporarily, has now been placed, with a second battery of sixty cells, in a separate building. The operation of the engine, using distillate in place of gasoline, has shown that electric power can be generated at very low cost on Mount Wilson, in spite of the heavy expense of "packing" the distillate to the summit. The power plant, though originally designed for the purpose of the expedition for solar research, may possibly serve, with some additions, for the much heavier demands of the Solar Observatory.

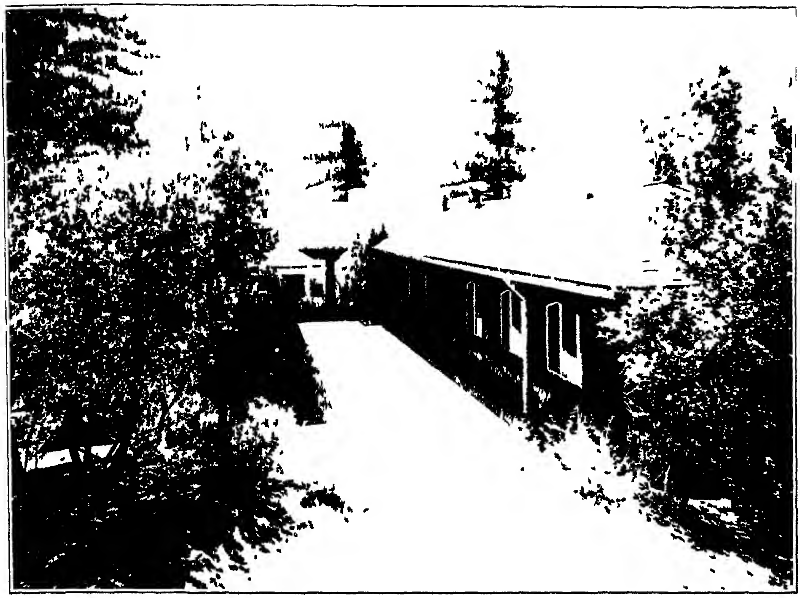
Storage-Battery House.—The intense heat experienced for a period of several days last summer and the limited space available in the small power-house led me to design an underground building of

concrete for the enlarged storage battery. This building, 13 by 13 feet in size, with cement floor and ventilated roof at the level of the ground, is large enough to contain a storage battery that seems ample for the purposes of the observatory. The number of plates in each of the sixty new cells may be increased from seven, the present number, to fifteen, when more storage capacity is needed. The thirty smaller cells of the former installment are used for special purposes, such as supplying power for the spectroheliograph motors, where great constancy of voltage is necessary to give photographs free from lines or bands due to irregular motion. The Snow telescope-house, laboratories, "Monastery," guest house, and shop are supplied with electric lights.

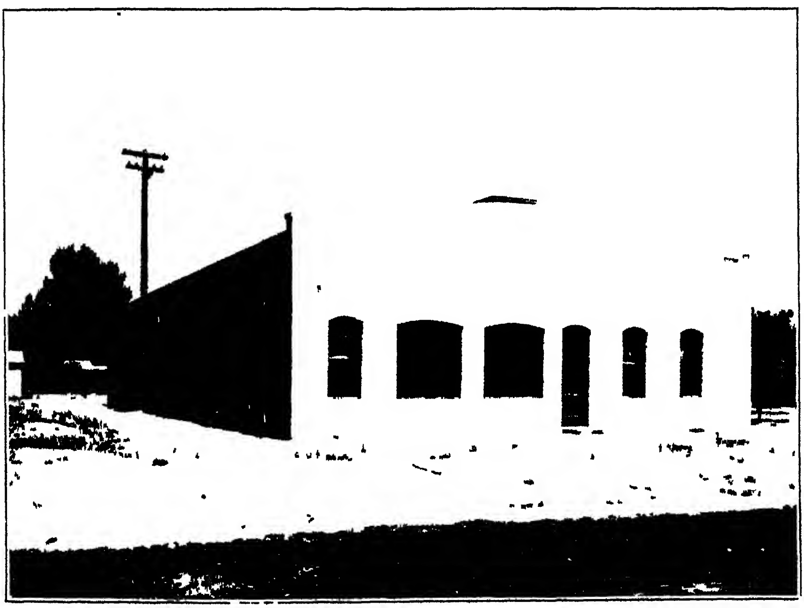
Pumping Plant.—The water system was installed during the past summer. A small house built of cement blocks, situated at Strain's Camp, contains a Deane triplex pump, connected with a 3½ K. W. direct current motor driven by the dynamo at the power-house. The water is raised about 325 feet and carried to a concrete reservoir of 30,000 gallons capacity, situated near the north end of the Snow telescope-house, about 2,100 feet from the well. All the buildings are supplied with water from the reservoir.

Fire Protection.—The danger from forest fires on Mount Wilson has led me to take special precautions to protect our buildings. During the past summer the Solar Observatory has coöperated with the U. S. Bureau of Forestry in the construction of an extensive system of fire-breaks, guarding Mount Wilson at the most vulnerable points. It is hoped that this system may be extended next year, as it protects both the observatory and the important station of the Bureau of Forestry at Henniger's Flats. In this connection I wish to express our appreciation of the interest in the observatory shown by Mr. Gifford Pinchot, Forester, and by Mr. T. P. Lukens, in charge of the station at Henniger's Flats, under whose supervision the work has been done. I may add that the extensive work of tree-planting on Mount Wilson, so successfully inaugurated by Mr. Lukens, is likely to prove of great future benefit to the observatory.

A fire-pump, driven by an electric motor, has been established in a small house of cement blocks near the large reservoir. This pump will supply a special fire-extinguishing fluid, or water from the reservoir, to the main system of pipes connected with each building and also to a line of pipes surrounding the Snow telescope-house. Fire hose is available where needed and fire-extinguishers are placed in each building.



COURT OF 'MONASTERY"



PASADENA OFFICE AND LABORATORY

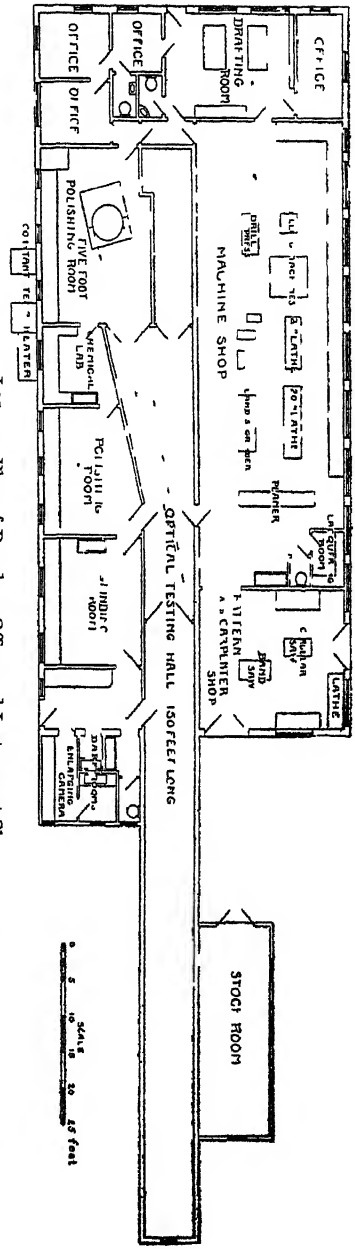


FIG. 1.—Plan of Pasadena Office and Instrument Shop

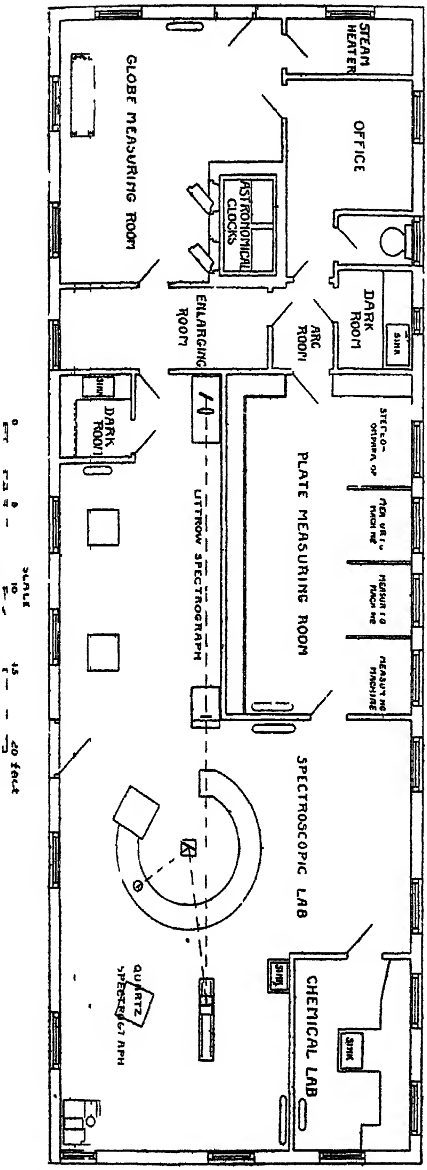


FIG. 2.—Plan of Laboratory at Mount Wilson

The "Monastery."—The offices and living quarters provided for the members of the staff in this building (described in Contribution No. 2) have proved very satisfactory. The library and current journals are also kept here. All the members of the staff, with the members of the visiting expeditions, meet regularly at meals in the common dining-room. The opportunity thus afforded for the informal discussion of scientific questions is one of the most attractive features of life at the observatory.

Guest-House.—The need of suitable accommodations for visiting men of science has been recognized by Mr. John D. Hooker, to whom we were already indebted for meeting the expenses of the Hooker Expedition. The guest-house, recently erected and furnished at Mr. Hooker's expense, contains two bed-rooms and a large living room, with broad piazzas extending the entire length of the building on the east and west sides. It has already proved of the greatest service in the entertainment of guests, thus serving as an important adjunct of the "Monastery."

General Laboratory.—The prompt and accurate interpretation of the results of astrophysical research is a matter of the first importance in planning the work of an observatory. On the one hand, if the observations, as in the present case, are made for the most part by photographic means, the problem of providing suitable devices for the measurement and reduction of the plates presents itself. In some instances the measures must be of the highest possible precision, while in others simple devices for measurement or computation may save a great amount of time and expense without in any wise detracting from the value of the results. Special attention has been devoted to these considerations. But it is not enough to accumulate a vast series of measures without undertaking such experiments as may be required for their interpretation. Accordingly, a laboratory has been built on Mount Wilson for the measurement and reduction of the photographs and the comparative study of the radiations emitted by various substances under widely different conditions of temperature, pressure, strength of surrounding magnetic field, etc. In order to provide against the destruction by fire of the collection of photographs, the building is constructed of cement blocks, with cement floor and partitions, metal ceiling, and metal-sheathed roof. It is 27 by 70 feet in size, and thus of sufficient length to contain the special globe apparatus for measuring solar photographs, already referred to in this report. Other measuring machines have also been mentioned in the discussion of the solar investigations. The chief apparatus in the spectroscopic laboratory

is a collection of light sources, including spark and arc in liquids or in gases at any desired pressure, electric furnace, Michelson tubes and mercury arc, Du Bois magnet for the Zeeman effect, etc., so arranged on a circular pier that by setting a mirror at the proper angle the light from any source may be focused on the slit of (1) a Fuess quartz spectrograph, giving nearly the whole spectrum on a single plate; (2) a Littrow grating spectrograph of 18 feet focal length; (3) a Pérot-Fabry interferometer, by Jobin, with auxiliary spectroscope; (4) a Michelson echelon spectroscope, by Hilger. It is hoped that this apparatus will be of great service in the interpretation of solar and stellar spectra. The laboratory also contains rooms for chemical experiments, photographic enlargement by electric and sky light, and developing rooms. It is heated by steam, lighted by electricity, and has ample electrical connections with the power-house and storage battery.

Warehouse.—A wooden building, 18 by 36 feet in size, has been erected near the power-house for storing building materials, etc. At present it is also used as a mess-house for the workmen.

Telephone Line.—A private telephone line, extending from the summit of Mount Wilson to the foot of the new trail, was constructed in the early spring of 1905. It connects with the lines of the Home Telephone Company, which were brought out to the foot of the trail for this purpose. All of the observatory buildings, including the pump-house at Strain's Camp, are in telephonic communication with one another, but instruments of the telephone company, connected with Pasadena, are installed only in the "Monastery" and the Snow telescope-house. The service is so good that letters can be dictated without difficulty to the stenographer at the Pasadena office.

Library.—A good working library is being purchased and installed in the "Monastery." It already includes complete sets of the Astronomische Nachrichten, Zeitschrift für Instrumentenkunde, Bulletin Astronomique, The Observatory, and Astrophysical Journal, and partial sets, extending back far enough to include the literature most needed in our work, of the Philosophical Magazine and the Annalen der Physik. Various standard treatises have been received, and the private library of the director, including sets of the Comptes Rendus, Proceedings of the Royal Society, Monthly Notices of the Royal Astronomical Society, Nature, and other journals, and a large collection of papers on astrophysical subjects, is also available. We are indebted to many individuals and to the directors of various observatories for the gift of books, pamphlets, and sets of publications.

PUBLICATIONS.

The publications of the Solar Observatory will include: (1) Contributions from the Solar Observatory, consisting of octavo papers printed also in the Astrophysical Journal (Nos. 1 and 2 have been distributed); (2) quarto volumes, forming part of the regular series of publications of the Carnegie Institution: (3) annual report of the director, from the Year Book of the Carnegie Institution, and (4) a series of reproductions of photographs, issued separately from time to time.

PASADENA OFFICE AND SHOP.

The Solar Observatory has no department more important than its instrument and optical shop in Pasadena, of which Mr. Ritchey is superintendent. When instruments of special design are needed in astrophysical research they are best constructed under the immediate observation of those whose ideas they embody. This fact, together with the saving of time and the facility of improvement or repair also afforded, has made a well-equipped instrument shop an essential part of a modern astrophysical observatory. Since the successful performance of the instruments constructed depends in large measure on the quality of the machine tools with which they are made, I have thought it wise to equip the shop with the best tools obtainable. These are enumerated in Contribution No. 2.

The shop, when first established in connection with the expedition for solar research (September, 1904), occupied rented quarters in Pasadena. The danger from fire and the necessity of having more space and special arrangements for optical work led to the construction of a substantial brick building in the spring of 1905. I wish to express our great obligations to the Board of Trade of Pasadena, which secured through public subscription funds sufficient to pay for two of the three adjoining lots (each 50 feet wide and 208 feet deep) occupied by the shop. I wish also to thank each of the contributors to the fund raised by the Board of Trade. The hearty interest shown by the citizens of Pasadena and Los Angeles in the Solar Observatory has helped us very materially. We hope that the observatory may ultimately prove of considerable public benefit. The space still available on the shop site (Santa Barbara street, near Lake avenue) will give ample room for the temporary erection of the 5-foot reflector mounting, the construction of a small building for the staff of computers, etc.

The new shop building, which is briefly described in Contribution No. 2, was first occupied in May, 1905. The machine and pattern

shops were immediately fitted up and brought into use, and the optical shop, which required special fittings, has been in operation since July. A 24-inch concave mirror of 143 feet focal length and a 20-inch plane mirror have been nearly completed, and work on the 5-foot mirror is in progress.

In addition to the large amount of work done in fitting up the shop and making special tools, etc., the following instruments have been nearly or quite completed:

- Spectroheliograph of 8 inches aperture and 60 inches focal length, with several sets of curved slits and various accessories
- Stellar spectrograph of 5 inches aperture and 13 feet focal length, with constant temperature case and support for large plane grating.
- Solar spectrograph (Littrow type) of 6 inches aperture and 18 feet focal length.
- Spectroheliograph temporarily used with the Snow telescope.
- Electric slow motions for 24-inch concave mirror of Snow telescope.
- Globe-measuring machine for solar photographs.
- Apparatus for removing the mirrors of Snow telescope from their cells when silvering.

All the patterns for the above work and much special furniture for the offices and laboratories have been made in the pattern shop.

FIVE-FOOT REFLECTOR.

The 5-foot mirror, which will form the principal optical part of the largest and most powerful telescope of the Solar Observatory, was brought out from the Yerkes Observatory last spring. It was packed with special precautions, under the personal supervision of Mr. Ritchey, in a double case, supported by two systems of spiral springs. The mirror arrived safely in Pasadena and is now being polished. Detailed drawings for the heavy mounting are being made by our draftsmen, under Mr. Ritchey's direction, and are so far completed as to enable the Union Iron Works Company of San Francisco to undertake work on the large castings. Several of these are finished and the nickel-steel forging for the polar axis has also been machined. There is every reason to hope that the mounting will carry the mirror with the high degree of precision necessary for the most refined photographic work.

INVESTIGATIONS OF STELLAR MOTION.

Boss, Lewis, Dudley Observatory, Albany, New York. Grant No. 230. (For previous reports see Year Book No. 2, p. xviii, and Year Book No. 3, p. 85.) $6,000.

Report.—Work has progressed effectively since the last report. Three assistants and four computers have been regularly employed. During the summer just passed four additional assistants have been employed on the investigation of errors of graduation of the transit circle.

In the last annual report the operations having in view the preparation of a preliminary general catalogue of bright stars were described, and the intention to complete this during 1905 was expressed. Work on this catalogue was pushed unremittingly, practically to the exclusion of everything else, until about May 1 of the present year. Then the work was temporarily suspended in order to throw the weight of the entire force upon the determination of errors of circle graduation, as hereinafter described.

The Preliminary General Catalogue of Stars is designed to furnish the positions for 1900, and the deduced proper motions, for every star in the sky, from the north to the south pole of the heavens, which is visible under favorable circumstances to an ordinary eye without the aid of a telescope. In addition to these, nearly as many more stars of somewhat less brightness are included, because they have been frequent subjects of observation in the past. Thus it is designed to include every star to which a statement of motion may be attributed with more than usual precision. There are about 6,000 of these stars. It is thought that this catalogue will temporarily supply a need that has long been felt by astronomical investigators in various lines, and that it will also afford the means for investigation of many stellar problems in a manner more satisfactory than that which has hitherto been possible. Eventually it is hoped to prepare on the same lines a catalogue of all stars down to the seventh magnitude. This work would include the facts relating to nearly 25,000 stars and would furnish a much broader and more satisfactory basis for investigation of problems relating to motion and structure in the sidereal system; but since the preparation of such a catalogue must still occupy several years, it is thought desirable to present in advance the fundamental part of it (the best-known stars) in the form of a preliminary general catalogue.

The foundation of the work for each star of the proposed catalogue is now complete. During this year ephemerides were constructed

for each star for which this work had not been previously accomplished. The comparison of observation with preliminary prediction had been completed for all except a few of the less well-determined star positions. During the year the equations have been formed and solved for about 1,500 stars in addition to what had been accomplished in previous years. All that remains to be done in these lines could be accomplished within four or five months if the entire force were to be concentrated upon that task: but it will be desirable to expend a large share of our potential upon the observations, leaving a safe margin for the completion of the Preliminary General Catalogue during 1906.

Work on the catalogue has been pushed forward, especially in the laborious revision of the systematic corrections applied to the several catalogues of observations. Great improvements in these corrections have been effected for the most extensive and important catalogues, though these present no material deviations from the results given in the Catalogue of 627 Principal Standard Stars, published in the Astronomical Journal two years ago. Much attention has been given to the determinations of corrections on account of "magnitude equation." The result is that we may consider this a problem substantially solved, in the sense that we are able to apply to the mean results for right ascension by the various observers of the nineteenth century the corrections which those observations require on account of the habit of the observer varying with the brightness of the star observed. The importance of this correction in relation to the study of systematic motion in the stellar system is fundamental. A great variety of special problems in relation to the systematic corrections required by the several catalogues of observation has been met and substantially solved, so that the completion of the work involves little more than routine operations, the extent of which can be accurately foreseen. Delays have intervened in the prosecution of this work.

The first delay in the work was caused when it was deemed advisable to renew the circle-graduations, and to push the determination of the errors to speedy completion, as a basis of all subsequent measurement in zenith distance according to our somewhat extensive program. A second and more effective cause of delay arose from the voluntary and high-spirited offer of Sir David Gill, Astronomer Royal at the Cape of Good Hope, to redetermine the positions of all the stars of our catalogue that are south of —33° of declination, some 1,200 in number, and to have the results of these determinations ready for me within a year from the time of beginning the observa-

tions. It was seen at once that this offer, successfully made good, would remove the most serious blemish to be anticipated in the Preliminary General Catalogue—the extreme weakness of existing material for computing the proper motions of many of the far southern stars. It was believed that the great improvement in results to be anticipated from these southern observations would far more than compensate for the delay. Accordingly, Sir David Gill's offer was accepted. Advantage will be taken to strengthen the determination of motion for about 600 of the stars north of —33° by special observations at the Dudley Observatory. These observations are already in progress. The completion of the Preliminary General Catalogue should easily be effected during 1906. Every effort will be made to insure against any default in this anticipation.

During the year several valuable transcripts of unpublished observations have been received for use in the preparation of the Preliminary General Catalogue. Notable among these contributions are: Positions from the new reduction of Groombridge's observations, 1810, and advance sheets for the entire catalogue, from the Astronomer Royal, Greenwich; transcripts of several thousand positions from the new reduction of Henderson's observations, 1840, from Dr. Halm, acting for Dr. Copeland, Astronomer Royal for Scotland; about 4,000 star-positions from the unpublished catalogue of the Cincinnati Observatory for 1900, from Dr. Porter, director; complete transcript of the unpublished Berlin Catalogue for 1890, from Dr. Küstner, director of the observatory at Bonn; a complete transcript of all the later unpublished observations of the Melbourne Observatory, from Mr. Baracchi, director (these cover observations extending over the past twenty years); positions of many stars from the unpublished recent observations at the Cape Observatory, from Sir David Gill. All of the observations are of very great use in our work because they relate either to very early or very late epochs, thus very greatly increasing the weight of determination for very many of the proper motions in our proposed catalogue. All these gentlemen, as well as others, are deserving of cordial thanks for the sympathetic and practical interest they have taken in this work.

In the division of observations during the past year much work of fundamental usefulness in relation to future operations has been accomplished. The use contemplated for the transit-circle in the projected observations, now actually begun, requires that, among others, two sources of error should be accurately investigated—deviation of the telescope from a plane normal to the axis of revolution, and error of graduation of the circles. These errors, always impor-

tant, but hitherto insufficiently treated at many observatories, are required to be known with substantial completeness and accuracy if the full benefit of corresponding observations in the two hemispheres, north and south, with the same instrument as contemplated, is to be realized.

Accordingly the pivots were reground and polished by the astronomical staff of the observatory during the autumn of 1904 with satisfactory results. On completion of this work the errors due to any outstanding deviations from cylindrical form of the pivots were thoroughly investigated by a special method found to be expeditious and efficient. The result, with description of method employed, has been published in the Astronomical Journal. The indications are that during a revolution of the telescope about its horizontal axis there is no deviation of the line of collimation from the normal plane greater than one-hundredth of a second of time.

Thorough examination of the circles last December disclosed the fact that the graduations in some places had become seriously impaired during the necessarily repeated polishing for removal of tarnish which the circles had experienced during 47 years of use. It became doubtful whether the elaborate results for correction of graduation-error obtained in 1894–1895 were still applicable. In short, it was determined to procure regraduation of the circles by Warner & Swasey, of Cleveland (Mr. Dudley Olcott, of Albany, having provided means for the purpose), and then to determine in the most complete and thorough manner the errors of the new graduations.

During the summer of the present year this work has been carried out, and has been extended to every multiple of 10′ for both circles. Moreover, the graduations, respectively distant 2′, 4′, 6′, and 8′ from the 10′ lines, have been investigated for systematic errors, with the result of finding that this error, though rather large, is wonderfully uniform throughout the circles. When the computations are completed the corrections for error of graduation, for each line on both circles, should be known with a degree of accuracy amply sufficient for the purpose. The "circle-readings" for the investigation proper occupied a little less than fifteen weeks from June 6. Seven assistants, with the director, were engaged upon the task. The observers worked in three relays in one-hour shifts, two persons being required in each relay, and the readings were kept up absolutely continuously from 8 a. m. until 5 p. m. every week day; but more commonly the hour of beginning was 7 a. m. It is estimated that about 450,000 micrometer measurements were recorded in this work. The reductions have been proceeding contemporaneously with the

observations, and they are now nearly completed. The degree of accuracy attained in the work is gratifying, affording bright promise for the effectiveness of the transit-circle in its future use.

Observations upon the projected catalogue for 1910 are now in progress. Tests thus far applied indicate that the precision which can be realized in determination of star positions with this instrument has been very substantially increased by the recent improvements of the instrument, entitling it to be ranked in the first class. Part of the program of observations for the coming year includes redetermination of star positions for the Preliminary General Catalogue (about 600 stars) in cases where there is dearth of modern observations or unusual difficulty in determining the motion from existing records of observation. Fundamental observations of the principal stars constitute, however, the chief element in the program; and for these it is believed that this transit-circle is well adapted.

Campbell, W. W., Lick Observatory, Mount Hamilton, California. Grant No. 101. *Pay of assistants to take part in researches at the Lick Observatory.* (For previous reports see Year Book No. 2, p. xix, and Year Book No. 3, p. 86.) $4,000.

Report.—The greater part of the income from the present grant thus far expended has been devoted, in the past year, to the employment of assistance in carrying on the spectroscopic investigation of stellar motion in the line of sight. For this purpose two men have been employed for the entire year, and two others for shorter periods. Besides the work of other members of the staff in this line, these assistants have secured 335 plates with the spectrograph.

Of the large number of spectrograms on hand, about 600 have been definitely measured in the past year by these assistants, besides over 100 that have been roughly measured. Investigations of several of the spectroscopic binaries have been included in their work, and a preliminary catalogue of such objects has been made.

In meridian-circle work the services of one assistant were available up to the end of June. He was occupied mainly in the microscope readings and the computations for the measurement of graduation error. The method employed was that of the simultaneous reading of both circles, and the total number of circle readings made for the purpose was above 16,000 for each observer, included within a period of eighteen months.

The determination of the corrections to the 10′ divisions will aid in adapting this instrument for fundamental work, since all the inter-

mediate divisions can be measured directly by means of the microscopes of one circle from the nearest 10′ division.

The measurement of the plates of Eros, secured with the Crossley reflector, has not yet been begun, but the services of the necessary computers have been engaged.

Davis, Herman S., Dover, Delaware. Grant No. 232. *New reduction of Piazzi's star observations.* (For previous reports see Year Book No. 2, p. xix, and Year Book No. 3, p. 87. $1.500.

Abstract of Report.—Meridian Circle: Determination of the constants of this instrument has been continued. Constants for 378 dates have been determined out of the 2,000 dates on which observations were made. A record of all observations from 1791 to 1813 has been compiled from the manuscripts by bringing together on separate cards all the observational data concerning each star, preliminary to application of the instrumental corrections and combination of the numerous observations into one mean for the definitive catalogue.

Transit Instrument: All the observations not arranged by Piazzi into regular corsi, but printed in the Storia Celeste as "Osservazioni Staccate," have been arranged in corsi and copied into printed forms. The reductions from apparent to mean place at 1800, for all dates and stars, have been computed, interpolated, verified by independent duplicates, and inserted where finally needed in the forms. Every time of transit on each of the five wires has been separately reduced to the mean of the wires for all dates and all stars and checked by duplicate.

The voluntary coöperation of Prof. J. G. Porter and Prof. R. H. Tucker in reobserving all the Piazzi stars for the epoch 1900 has been brought to a successful conclusion by their publication of the two catalogues mentioned in the bibliography of this Year Book, pages 48, 49.

This report closes 454 weeks of work on the new reduction. Within this time eighteen different persons have been engaged for varying periods of time, only two having worked continuously from the beginning to the present time.

Newcomb, Simon, Washington, District of Columbia. Grant No. 233. *Investigation of the mean motion of the moon from observations from the earliest historic times to the present.* (For previous reports see Year Book No. 2, p. xxi, and Year Book No. 3, p. 90), $2,500. Grant No. 254. *To aid investigations in mathematical astronomy, statistical methods, and economic science*, $5,000. $7,500.

Professor Newcomb submits the following list of researches which he has carried on with the aid of the above grants:

A Compendium of Spherical Astronomy with applications to the determination and reduction of positions of the fixed stars. This work was completed last June, has been accepted for publication by the Macmillan Company, and is now being printed.

Observations of the Zodiacal Light from the Brienzer Rothhorn, showing that this light, instead of being merely extended along the zodiac, as heretofore described, can be seen surrounding the sun on all sides. The observations and conclusions were published in the Astrophysical Journal for October, 1905.

On the Eclipse of Agathocles (Monthly Notices Royal Astronomical Society, vol. LXV, No. 2). This eclipse seems to strengthen the conclusion that the actual retardation of the earth's rotation from century to century is much smaller than was formerly supposed.

The reduction of occultations of stars by the moon observed since 1750, with the correction of the moon's motion from them, is practically completed, so far as the heavy computations are concerned. This work on the motion of the moon is to some extent carried on in coöperation with the Royal Observatory, Greenwich, the latter being engaged in working out the results of the meridian observations of the moon made at that institution.

Investigation of the action of the planets on the moon. This proved to be a necessary adjunct to the derivation of results from the occultations, and was therefore carried on in connection with the other. Professor Newcomb is actively engaged in securing the completion of this work.

Discussion and comparison of the temperature of the air at various widely separated points on the globe, from 1871 till the present time, with a view of determining whether the amount of heat radiated by the sun is subject to appreciable change from time to time. The working up of the data for this work has been somewhat delayed, but its completion requires little other than routine computations, which are proceeding as fast as circumstances permit.

Dr. Frank E. Ross, acting as principal assistant in the works on the moon, has completed and published the following:

Investigation of the orbit of Phœbe, the ninth satellite of Saturn.—This work has been published by the Harvard Observatory in volume LIII, number 6, of its Annals.

Preliminary orbits of the sixth and seventh satellites of Jupiter.—This work has been published by the Lick Observatory in numbers 78 and 82 of its circulars.

BIBLIOGRAPHY.

Fletcher, Robert, Army Medical Museum, Washington, District of Columbia. Grant No. 234. *Preparation and publication of the Index Medicus.* (For previous reports see Year Book No. 2, p. xxiii, and Year Book No. 3, p. 95.) $10,000.

Report.—After the publication of the report in the last Year Book the volume of the Index Medicus for 1904 was completed. It formed a large octavo volume of 1,201 pages, the index of authors and subjects occupying 205 pages in addition. The index of subjects brings together, under separate headings, all references to every subject in the twelve monthly parts. Of the volume for 1905 the numbers to October, inclusive, have appeared. The scope of the work becomes enlarged each year with the increase in the number published of medical books and periodicals. In the Index Medicus for 1904 there appeared over 3,800 titles of new medical books under their appropriate subject headings, and during the same period about 1,400 periodicals were regularly indexed. Laboratory work, not only in biology, but in everything relating to the public health, has also much increased in the number of its publications. The formidable epidemics of plague, cholera, and yellow fever, which have to some extent reappeared during the present year, have already brought numerous reports to medical journals and societies. These are indexed and made available for officers of health and the medical profession generally.

It is interesting to observe the extent to which the Index Medicus is made use of abroad. Its subscribers, though chiefly residents of the United States, are also found in Australia, Austria-Hungary, Belgium, Bohemia, Canada, Canal Zone (Panama), Denmark, England, Finland, France, Germany, Holland, Ireland, Italy, Philippine Islands, Portugal, Roumania, Scotland, Spain, Sweden, and Switzerland.

Putnam, Herbert, Library of Congress, Washington, District of Columbia. Grants Nos. 107 and 290. *Preparation and publication of a Handbook of Learned Societies.* (For previous reports see Year Book No. 2, p. xxiv, and Year Book No. 3, p. 97.) $5,500.

Mr. J. David Thompson, chief of division of documents, Library of Congress, has been acting as editor of the Handbook. He submits the following report:

Except for current notes of publications of foreign societies, the whole time of the office force has been devoted to preparing for the

press the volume for North and South America. Innumerable difficulties have been encountered which could not have been foreseen. The inaccuracy and inadequacy of the information supplied by the societies themselves in many cases have made it necessary to carry on a great deal of supplementary correspondence, both with the societies and with the libraries which have complete files of their publications. The early publications of many of the societies are bibliographically very irregular and there exists no printed information on which reliance could be placed. Difficulties of this character will be fewer in the case of most foreign countries, because there is a considerable number of reliable bibliographies to which reference can be made.

Volume 1, *i. e.*, North and South America, is now in the press. About 100 pages are already in type.

The engagement of the regular office force will be terminated at the end of October. This will leave practically all of the supplementary grant made in the spring of this year still available for proof-reading in the various foreign languages in the remainder of the Handbook. The completion of the editorial work for the foreign societies and the printing of the remaining volumes will take about twelve months longer.

In October of last year a brief account of the undertaking was presented at the conference of the American Library Association at St. Louis.

Weeks, F. B. (under direction of Dr. G. F. Becker). *Bibliography of Geophysics.* Grant No. 170. (For first report see Year Book No. 3, p. 81.) $5,000.

The work has been conducted by Mr. Weeks for a period of seven months, April 1 to October 1. The references are being brought together under the following general heads, leaving the minor subject heads to be determined after all of the literature has been examined: General works and text-books; bibliography; periodicals; cosmical physics, divided into earth-moon system, meteorites, origin, constitution; origin of earth, divided into nebular and other hypotheses; movement of earth in space; rotation of earth in space; terrestrial magnetism; electric earth currents; auroras; earth's interior, divided into magmas, rocks, igneous rocks, and vulcanism; lithosphere, divided into origin, etc., and diastrophism; metamorphic rocks; sedimentary rocks; ore deposits; earthquakes; atmosphere; hydrosphere; climatology; glaciology; geologic processes; physiography; ocean topography; and geologic history.

BIOLOGY, EXPERIMENTAL.

STATION FOR EXPERIMENTAL EVOLUTION AT COLD SPRING HARBOR, NEW YORK.*

By Charles B Davenport.

In planning an experimental study of evolution, investigations already in progress elsewhere were taken into consideration in order that work might not be duplicated, but rather that the more difficult, expensive, and time-consuming operations might be taken up, and that there might be brought about a coördination of the work being done in the subject all over the world.

The factors of evolution are three—variation, inheritance, and adjustment. Studies may be made on any one of these factors or on all three together; as a matter of fact, they can hardly be studied wholly independently. Variation has been much studied during the past decade by quantitative and other methods. These have been studies in evolutionary statics and have required no special plant. Since these studies can be as well made elsewhere, we have devoted little time to them. Inheritance of variants is a dynamical matter whose investigation is beyond the ordinary facilities of universities as at present organized, and requires continuity of work during long periods of time. Variants are of more or less significance for evolution, according to the method of their inheritance: so the study of heredity furnishes a test of the importance of the different kinds of variation. Since studies in inheritance have been relatively neglected, despite their importance for evolution, our first efforts have been directed primarily toward such studies. To lead to valid generalizations, such investigations should be made broadly; consequently work has been or is planned to be undertaken in coöperation with others on all the main groups of animals and plants.

There are two ways in which the work might be divided among the workers—by topics or by material. While the investigation of a topic by one person would be under conditions of completer knowledge the ideal method, it is better, in present practice, to divide on the basis of materials to be studied. The reason for this is that, especially among animals, each kind of material offers special difficulties in rearing and breeding that have to be mastered before further progress can be made; and the mastery of the difficulties in the breeding of a single species may demand an investigator's whole attention during one or many years.

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* Grant No. 218. $12,000 for investigations during 1905. (For first report see Year Book No. 3, pp. 23–32.)

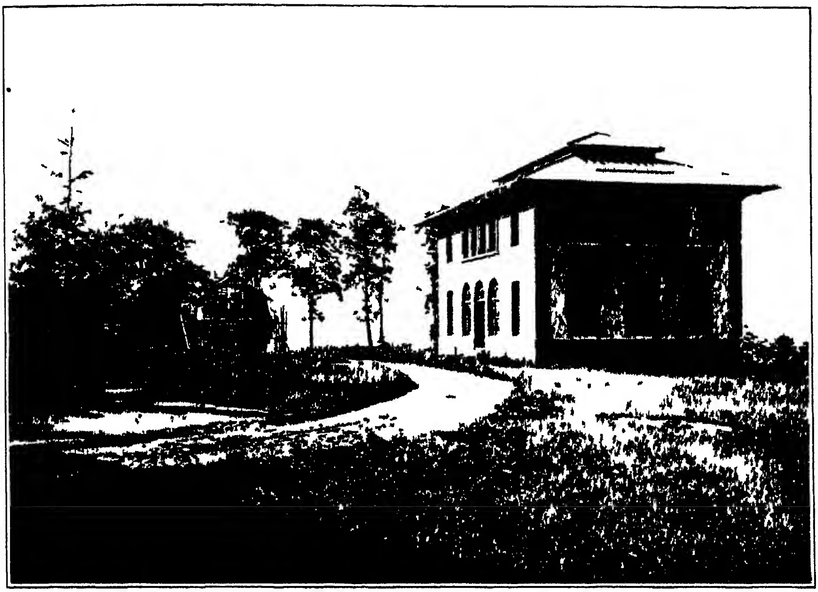
The work in progress may be classified into the following departments:

1. Investigations into inheritance and variability of plants.
2. Investigations into inheritance and variability of insects.
3. Investigations into inheritance and variability of other invertebrates.
4. Investigations upon aquatic vertebrates.
5. Studies on inheritance in domesticated animals.
6. Investigations into the cytological basis of heredity.
7. Cooperation with other investigators.
8. Work of subsidiary departments.
9. Care and development of the plant.

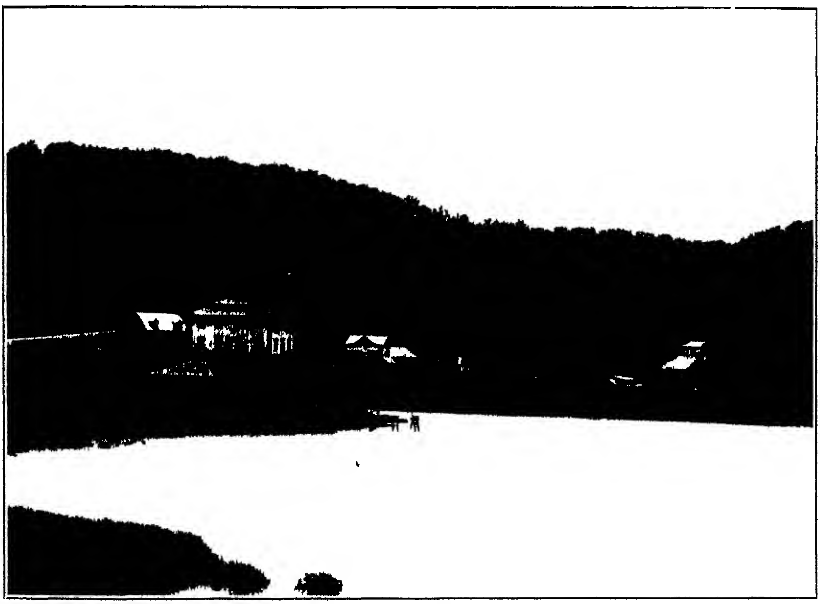
INVESTIGATIONS INTO INHERITANCE AND VARIABILITY IN PLANTS.

Since plants get their food from the soil and air, their maintenance is less expensive than that of animals; since they are stationary, less caging is required; but, on the other hand, since their fertilizing element is for the most part scattered by the wind or by insects, interbreeding is more difficult to control. Moreover, it is necessary to fight the other plants, weeds, with which they come into competition, parasitic plants and animals, and meteoric conditions of precipitation, temperature, and wind. About 2½ acres of land are devoted to the rearing of pedigreed plants. The fundamental physical conditions of the soil are satisfactory, and sufficient manure can be purchased in the vicinity. One laborer has been able to keep the ground cultivated. Danger from drought will be henceforth avoided by the new water system about to be installed. The out-door temperature favors growth during the season, and the growing season for certain plants will be continued through the year by the propagating house now nearly completed. The advantage of plants for studies in inheritance depends on the great number of characters that they offer and the comparative ease with which cross-fertilization, even between distantly allied forms, may be secured. On account of these advantages they have been more used for studies in heredity than animals.

The botanical investigations are at present being carried on by Dr. G. H. Shull alone. The work has been so multifarious as to demand an immense amount of his time. His report is given on pp. 96–100. As Dr. Shull reports, we have coöperated in our plant-breeding with Drs. Britton and MacDougal, of the New York Botanical Garden. Visits between the Station and the Garden by the staff of each have been numerous, and consultations on matters of mutual interest have been repeatedly held.



VIEW OF THE MAIN BUILDING OF THE STATION FOR EXPERIMENTAL EVOLUTION—FROM THE SOUTH.



GENERAL VIEW OF THE GROUNDS AND BUILDINGS OF THE STATION—FROM THE EAST.

Beginning at the road at the left there is shown first the stable, next the main building and behind and above the director's residence Then come a green-house a colony house for poultry, and an instrument shelter Further to the right appear a number of small colony houses in a poultry yard, then the station launch and boat-house, behind the latter a brooder and pigeon house Cold Spring Harbor in the foreground

INVESTIGATIONS ON INSECTS.

Insects are probably to-day the most rapidly evolving of all organisms. This conclusion is based on their great variability. The number of described species is reckoned at hundreds of thousands, about equal to the number of all other animals put together. The static study of their variability has long been carried on, but relatively little breeding of them has been done because of the technical difficulties. The greatest difficulties are uncertainty of pairing in captivity and the infertility of many crosses. To circumvent these difficulties it will be necessary to devise special methods of housing and caging them. We are planning an insectary. Smaller cages for individual experiments are being constantly devised. Each experiment with a new kind of insect requires a careful study of conditions of food, moisture, temperature, light, and air. Changing food of the insects and keeping the cages clean take much time and limit the number of experiments that one man can undertake; consequently results from insects come rather slowly at first. Fortunately they breed rapidly and produce a great number of offspring; so when the technical difficulties are overcome they should prove the best of material for our studies.

Mr. F. E. Lutz has attacked the difficulties of breeding insects with energy and success, and, barring accidents, should gain important results by another season. His report will be found on page 100.

Mr. Roswell Hill Johnson, who began work here in August, is working on lady birds (*Coccinellidæ*) a family of beetles which contains thousands of species, many of uncertain systematic status. They feed on plant-lice (aphids). His experiments have led him to undertake the systematic cultivation of aphids by rearing their food plants, and even to a study of their diseases. Mr. Johnson reports on page 102.

Prof. W. J. Moenkhaus, of Indiana University, associate of the station, worked during two months of the summer at the station upon the question of sex-inheritance, using some small, rapidly breeding flies for the purpose. He reports on his work at page 102.

Prof. H. E. Crampton, Columbia University, an associate, has been working on selection in the Saturnid moths. He has made use of the facilities of both the biological laboratory and the station for his breeding work.

Mr. W. L. Tower, University of Chicago, an associate, has continued his investigations on the evolution of the Colorado potato

beetle and its allies in Mexico. He has a large report on earlier investigations ready for the press.

Dr. J. H. McGregor, of Columbia University, worked both in connection with the station and the biological laboratory upon inheritance in bees.

INVESTIGATIONS ON OTHER INVERTEBRATES.

Some *Helix nemoralis* of the Virginia colony are being bred to test inheritance of their variable markings. The snails are kept in 32 compartments out of doors. Results are not advanced enough for report. We have experimented with breeding various other species in captivity.

INVESTIGATIONS UPON AQUATIC VERTEBRATES.

Fishes afford excellent material for studies in inheritance, because they produce great numbers of offspring and because even distantly related forms are easily cross-fertilized. Dr. W. J. Moenkhaus, of Indiana University, who has published important investigations on the behavior of the germ plasm in fish hybrids, continued his work on hybridization of fishes at the station in the summer of 1904. His detailed report is given below. At present the station possesses about 100 crosses between brown trout and albinic sports of the same species. The crosses are pigmented exactly like the brown trout. This material was presented to the station by the New York State Forest, Fish, and Game Commission. The fish were bred by Mr. Grant E. Winchester at the Adirondack hatchery. We obtained them through the interest of Mr. John D. Whish, secretary of the commission. It appears that some albino trout suddenly appeared at the Adirondack hatchery, and that they were successfully reared to maturity. Some albino progeny were obtained, but these proved too weak and nearly all eventually died. Meanwhile Mr. Winchester had fertilized 424 eggs from the normal female with the albino male. The offspring, as stated, resembled the normal fish. On April 26, 1904, I wrote to Mr. Whish, urging that the hybrid eggs be kept separate from the others, and concluding: "I predict that if these fish are crossed with each other, when they become mature they will yield pure albinos in 25 per cent of the offspring, and that such albinos thereafter intercrossed will produce nothing but albinos." To test this prediction, the young hybrids are being reared partly at Saranac and partly at Cold Spring Harbor. As our fish ponds are not yet ready, the fish are being taken care of at the State fish hatchery, adjoining our grounds, through the kindness of Mr. Charles H. Walters, superintendent, and it is proposed to breed from them the present autumn.

STUDIES ON INHERITANCE IN DOMESTICATED ANIMALS.

This has been my major investigation. The following species are being bred at the station :

Systematic name	Common name.	Number of original stock.	Number reared at station.
Gallus bankiva	The jungle fowl		8
G. domestica	The domestic fowl		810
Anas domestica	The domestic duck		10
Columba livia...........	The house pigeon.......		14
Serinus canarius	The canary bird........		90
Fringilla cardualis	European goldfinch.....		†4
Capra hircus.....	The domestic goat......		4
Ovis aries..	The domestic sheep		2
Bos taurus *.	Domestic cattle....		2
Felis domestica.... ..	The domestic cat.....		

*In coöperation with Dr. Walter B. James. † Hybrids.

The results with poultry and those with canaries will be made the subject of special papers upon which I am now at work. A progress report will here be made upon the mammals bred.

Goats.—Two Irish goats were purchased in September, 1905. The male possesses a pair of well-developed accessory auricles and the female has a very small accessory auricle (wattle) on the right side of the neck ; on the other side there is no extra auricle, but a change in color of the hair marks the site where it has failed to develop. The interest attaching to the accessory auricles depends on the facts that they are typical abnormalties and subserve no function. They have been repeatedly observed in man and are sometimes associated with cervical fistulæ. They are regarded as serially homologous with the normal auricles. Among domesticated animals they are found in pigs, sheep, and goats. The sheep of the Wilster marshes are said to have the auricles associated with a neck bare of wool, and in the Merino breed, as a whole, this abnormality is especially common. A case of inheritance of these pendants is cited by Bateson (Variation, 1894, p. 180). Gouboux (Rec. de Med. Veter., ser. 3, IX, p. 335) gives a case of two she-goats on a farm, one having cervical appendages, the other having none. Each gave birth to a pair of kids at the same time. Each pair consisted of a male and a female, and in the one the male only had the appendages, in the other the female only. The characteristics of the sire of these kids were not known.

Our female goat produced January 12, 1905, at the station, of unknown paternity, two kids—one male and one female. The female

kid only had accessory auricles. The female goat again gave birth on September 19, 1905, to two kids by the wattled male—one a male and one a female. The male kid only has accessory auricles. Consequently it is probable that both of the wattled parents are heterozygous, and that the non-wattled condition is in them recessive. On this hypothesis we should expect, with larger numbers, to get three times as many wattled as non-wattled offspring. In regard to the inheritance of coat color, I may say that both parents are of mixed color—black, white, and buff. Of the first offspring (sire unknown), one was pure white and the other buff and white. Of the second pair, one is black and the other buff and white.

Sheep.—The valuable gift to the station by Dr. Alexander Graham Bell of two 5-nippled ewes and one 6-nippled ram, born in the spring of 1904 in his Nova Scotia flock, was mentioned in my first report. One of the ewes is white like the ram; the other is black; all are thriving. Two horned Dorsets--a race that has the reputation of bearing twins—were purchased in December, 1904, of W. R. Selleck, Huntington. Both were in kid and each gave birth to one young in the spring of 1905. I am consequently disappointed in my strain, but as the Dorsets are still young there is a chance that they may improve in fecundity. Meanwhile the examination of sheep at county fairs has shown that 3 or 4 nippled individuals are not rare on Long Island, and goats and cows with extra nipples can be procured; and it is proposed to extend experiments in the very practical direction of increasing the number of functional mammary glands.

An examination of Dr. Bell's printed list of multinippled sheep has brought out an interesting fact in regard to the inheritance of color. In all cases (20) but one, when both parents are black the offspring are black. From correspondence with Dr. Bell it appears that the one exception may be due to an error in the record. It may be concluded, therefore, that two blacks always throw blacks only. This indicates that black color is a Mendelian recessive in sheep.

Cattle.—The two chief races of dairy cattle, Jersey and Holstein, are characterized by a great difference in color, build, and quantity and quality of milk. I have wished to see if the quality of the Holstein milk, noted for its remarkable quantity, could be improved by breeding with the Jersey. Owing to the practical importance of the proposed experiment, it should be carried out by some one with greater resources than we have. It will probably be necessary to proceed on a small scale, trusting to the chance of the single die throw, instead of the certainty of the frequently repeated, to get a favorable combination of characteristics (viz. quality and quantity) in the second hybrid generation.

Cats.—If characteristics are for the most part inherited entire and can be combined in various ways, like atoms in chemistry, it should be possible to obtain any desired combination. At the beginning of the year I set myself the task of producing a white, blue-eyed, deaf. long-haired, tailless, polydactyl cat. My parental stock consists of: No. 1, black Manx male (tailless); No. 2, black, tailed, polydactyl female; No. 3, female Maltese polydactyl; No. 4, white, blue-eyed, deaf, polydactyl female; No. 5, black and yellow polydactyl female. The Manx male was bred to these females. The results so far are represented below in tabular form.

[Abbreviations: N, black; W, white; Tig., tiger, Malt., maltese; Gy., gray.]

				Hair color.				Eye.		Hearing.		Hair.		Tail.		Toes	
	No. to lit	Cat No.	Sex	N.[1]	W.	Tig.	Malt.	Gy.[1]	Blue.	Acute.[1]	Deaf.	Short.[1]	Long.	Pres.	Abs[1]	Norm.[1]	Abnor.
Mothers. 3 ♀							×	×		×							{7–7 5–5}
	6	6	♂			×		×							×		{6–6 6–6}
		7	♀				×	×						×		{5–5 4–4}	
		8	♀				×	×							×		{7–7 5–5}
		9	♀	×				×							×	×	
		10	♀				×	×							×	×	
		a	♂				×								×	×	
					×				×		×	×		×			{7–7 5–5}
	5	14	♀		×				×		×	×		×		×	
		h			×										×	×	
		i												×		×	
		d					×								×		{6–6 5–5}
		e				×									×	×	
				×				×						×			
	2	11	♀			×								×		×	
		12	♂	×				×							×		{6–6 5–6}

[1] Paternal characteristics.

As a result, I obtained a great variety of combinations of characteristics, viz:

Black, tailed, normal toed........................ No. "c."
Do. tailless, normal toed............................ No. 9 ♀.
Do. tailless, abnormal toed........................ No. 12 ♂.
White, tailed, normal toed........................ No. 14 ♀.
Do. tailless, normal toed........................... No. "b."
Tiger, tailed, normal toed........................ No. 11 ♀.
Do. tailless, abnormal toed........................ Nos. 6 ♂, "e."
Maltese, tailed, normal toed..................... No. 7 ♀.
Do. tailless, normal toed........................... Nos. 10 ♀, "a."
Do. tailless, abnormal toed........................ Nos. 8 ♀, "d."

CYTOLOGICAL INVESTIGATIONS.

The results of the last three years confirm the belief in the importance of the chromatic material in inheritance. This chromatic material exhibits a bewildering complexity and diversity scarcely less than that of adult organisms. It is of the greatest importance to find the relation of chromatic diversity and somatic diversity. Miss Lutz has made progress in this difficult and time-consuming work (page 101).

COÖPERATION WITH OTHER INVESTIGATORS.

It has been part of the plan of the station to come into friendly and coöperative relations with workers in our field everywhere. This idea has been carried out by the establishment of the two classes of associates and correspondents, the former constituting a non-resident staff of the station, the latter other workers in the same field. We have added to the list of our correspondents the following:

Prof. E. B. Poulton, of Oxford University, England. Professor Poulton has long been known for his experimental researches upon the adaptive significance of color-markings in animals and their control in many cases through direct stimulation.

Mr. A. D. Darbishire, of Owens College, Manchester, England, who has published a series of papers giving the results of his experiments on breeding mice.

The titles of a number of works in experimental evolution published by our associates and correspondents and showing the present trend of the science are given on pages 106 and 107.

A large number of biologists have visited the station to view the work or to consult on general methods or special points in their work. We have gladly given much time to such inquirers.

Miss Edith M. Brace, of the Western Maryland College, spent two or three weeks at the station studying the physiology of the snake's tongue. Mr. Ivey N. Lewis, of Johns Hopkins University, was accommodated during about six weeks of the early spring while making collections of Coleochæte, parasitic on the water-weed *Nitella*, for further investigation.

WORK OF SUBSIDIARY DEPARTMENTS.

The library is an important adjunct of the literary part of our scientific work. An extensive library of biological literature was clearly out of the question; moreover, it is not necessary on account of our proximity to New York City. But one kind of a library has been regarded as essential. Our isolation has demanded that we should have a set of synoptic works on systematic and anatomical

biology; complete bibliographic indices, so that we may know what has been published and is being published on any biological subject that we may have to refer to; as nearly as possible, all the more important speculative and experimental books and papers dealing with evolution, including variation, heredity, and plant and animal breeding; and current zoötechnical and phytotechnical journals, that we may learn of advances in methods of caring for animals and plants and keep advised of available material. Our accessions of bound books number 575. During the winter of 1904–05 the library was installed and catalogued by Miss Mabel E. Smallwood.

During the winter and spring the staff met regularly to review the articles bearing on experimental evolution that appeared in the literature received.

The papers of the station, of which three have already appeared and three others are nearly ready for the printer, have been distributed to over 250 learned societies and institutions, from which we are receiving many publications in exchange. We receive currently the publications of nearly all of the State agricultural experiment stations.

The necessity of making records by photography has led us to furnish the dark-room quite fully. Mr. H. A. Hackett divided his time between making photographs and helping care for the poultry. Animal photography is the most difficult phase of the art. We need the best lens attainable for this purpose and have included the purchase price in our budget for next year.

The observations of the meteorological instruments have been made daily, under the charge of Mr. F. E. Lutz.

CARE AND DEVELOPMENT OF THE PLANT.

On January 1, 1905, the station building was finally ready for occupancy, and our real work under satisfactory conditions must date from that time. The building is substantially made, is semi-fireproof, and is highly convenient for our work. That work has, however, grown so far in excess of our anticipations that it has already become evident that the building is to be used chiefly for office work and the preservation of books and records, and that the breeding of organisms will be done in separate buildings. In pursuance of this plan, there have already been erected one poultry-house 10 feet by 60 feet, a brooder-house about 30 feet by 40 feet, and a green-house 59 by 18 feet; 14 small chicken-houses have been purchased, and it is intended to construct about 20 more. A glass-covered vivarium for rearing insects and snails is also planned. We hope in time to have a substantial birdhouse, with flying-cages, for breeding canaries, sparrows, and other small birds.

The completion of the main building left us with a large number of finishing operations that could be completed only in the spring. At that time the ground about the building was graded, a drive made from the highway to the building, the water system completed, and the electric cables finally laid. During the coming year we plan to introduce a new water supply, which will furnish about 2,000 gallons of water per hour, with a head of 20 feet, to be used for the fish-ponds, the indoor fish-troughs, and irrigation of the gardens, green-house, and insectary. It is hoped also to complete the salt-water system to the main building

The general care of the place—cutting grass, keeping drive in order, and washing windows—has required some attention and has been done by a laborer, who has, in addition, dug ditches for draining, water pipes, and cables, done detailed grading, and helped in many of the heavy operations.

It is a feature of experimental work in biology that it tends to increase geometrically, and it is evident that more land will eventually be required.

That the work of the station is widely known and generally appreciated is shown by the variety of gifts received from many sources. These comprise books and papers pertaining to the work, together with interesting specimens of animals, plants, and so forth.

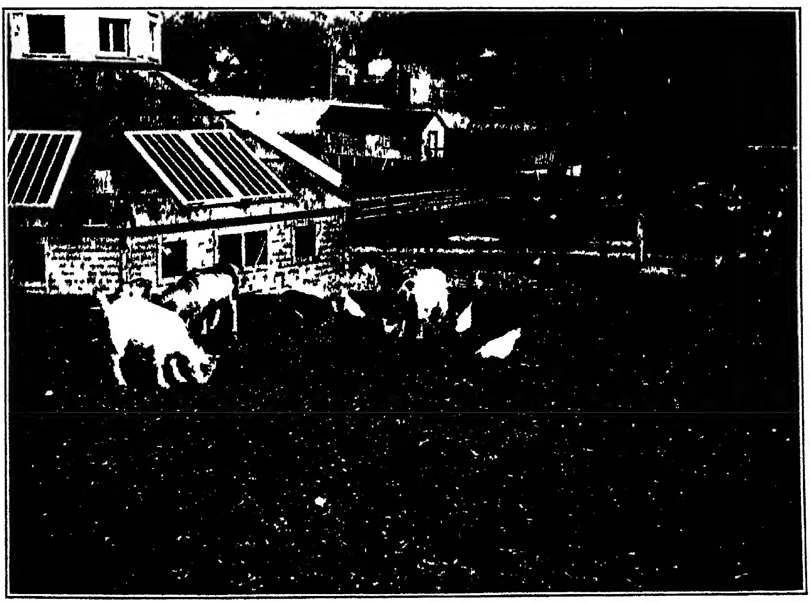
The station is especially indebted to Dr. O. L. Jones for the gift of much sand, gravel, and forest loam, as well as for numerous other courtesies.

REPORT OF DR GEORGE H SHULL.

The botanical experiments may be considered under the two natural subdivisions, variation and inheritance. Recognizing that variations are of two kinds, mutations and fluctuations, both of which doubtless have important bearing upon evolution, the study of variation resolves itself into (1) a search for mutations, and (2) the investigation of the causes, modification, and fixation of fluctuating characters.

In the search for suitable material for studies on the origin and permanence of variations among plants, 160 lots of seeds were collected, representing 108 species. Certain limitations of space available for germinating and caring for these plants made it impossible to handle so many lots; consequently a selection was made involving 128 lots of seeds of the 81 species that were thought to be most promising. Sowings of the biennial and perennial species were made in the latter part of February and early in March with the hope that

PART OF MAIN EXPERIMENTAL GARDEN OF THE STATION, JULY, 1905.
Evening primroses in the foreground, Russian sunflowers at the right, Indian corn at left



VIEW OF PART OF SHEEP AND GOAT PASTURE AND POULTRY RUNS. BROODER HOUSE TO THE LEFT.

they might thus be brought to flower and fruit in the first season, but only in the evening primroses was this hope fulfilled. Owing to an unfortunate delay of two months on the part of the Bausch and Lomb Optical Company in filling our order for a soil-sterilizer, recourse was had to means other than sterilization to avoid the contamination of the cultures with seeds of unknown origin. For this purpose sand was taken from a sand bank after the careful removal of the portion which might have received seeds carried by wind, birds, etc., or which might have been brought down from above in landslides. Many of the species chosen for these studies were woodland plants which find the best conditions for their development in a soil rich in humus. The attempt to start them in sand resulted in a greatly lessened measure of success in the germinations than might reasonably have been expected if they had been sown in soil. Of 128 lots of seeds sown, only 69 lots gave germinations, and in many cases only one or several specimens of a species were secured. Species having very small seeds, such as *Hypericum* and *Mimulus*, reached the limit of their development before they were large enough to be successfully transplanted from the sand to boxes of soil.

The number of pedigree-cultures which finally found their way into the garden was 48, belonging to the following 28 species:

Aquilegia canadensis
Barbarea sp.
Bursa bursa-pastoris
Sibbaldiopsis tridentata
Potentilla monspeliensis
Viola arvensis
Chamænerion angustifolium
Oenothera gigas
Oe. lamarckiana
Oe. lata
Oe. nanella
Oe. rubrinervis
Kneiffia pumila
Lappula americana
Verbascum blattaria
Plantago lanceolata
P. major
Sonchus asper
Lactuca canadensis
L. spicata
Ambrosia artemisiæfolia
Chrysopsis falcata
Solidago alpestris
S. macrophylla
Erigeron ramosus
Rudbeckia hirta
Helianthus annuus
H. debilis

In addition to these, the following species have been under observation, but were kept indoors, owing to their late germination:

Draba incana arabisans
Trifolium pratense
T. hybridum
Mimulus ringens
Chelone glabra
Pentstemon pentstemon
Viola spp.
Sonchus oberaceus

The chief ends aimed at in the inception of these pedigree-cultures were: First, to determine in each case the presence and characterization of any elementary species within the systematic species; second, to observe the nature and degree of the fluctuations normally present, in order to give a basis for selecting those variations which may be expected to prove transgressive or mutational; third, to learn

such biological relations for each species as capacity for self-fertilization, either with or without artificial aid, adaptations for crossing, number of viable seeds produced, etc.; and, fourth, to find out their capacity for successful manipulation, both as regards ease of culture and of adequate control of the fertilization processes.

Of the species that have been under observation this year, several have shown notable variations, but the exact significance of these can be known only when continued culture shall have shown their behavior in inheritance.

In the study of the laws governing fluctuating variations, material has been collected for the investigation of secular variation in the ray-flowers of *Chrysanthemum leucanthemum*, a small plot has been set aside and fenced as a permanent chrysanthemum preserve to supplement the work I have done on *Aster prenanthoides*, and arrangements have been made for continuing the studies on the latter species.

The influence of self- and cross-fertilization and of the selection to particular types upon fluctuating variability and upon the fixation of fluctuations is being studied in *Zea mays*, the character chosen for this study being the number of rows on the ear.

The relation of fluctuating characters of mutants to the corresponding characters of the species from which they originated and the question as to whether or not there is any tendency on the part of the mutants to regress toward the parental condition has been investigated in *Oenothera lamarckiana*, *Oe. rubrinervis*, and *Oe. nanella*, and the results were published as part of Paper No. 2 of the Station for Experimental Evolution, entitled "Mutants and hybrids of the Oenotheras," by D. T. MacDougal, assisted by A. M. Vail, G. H. Shull, and J. K. Small. I have again collaborated with Dr. MacDougal and Miss Vail in a continuation of these studies, which will be published soon in the series of papers from this station.

Although experimental evolution is naturally divided into variation and inheritance, it must always consist in a combination of these two processes, so that in most cases the investigations involve both elements. Inheritance is always the test of mutations, and it is likewise involved in every problem of selection; but in the studies already mentioned variation is the prime object, while in those that follow, the laws of inheritance are the chief object in view.

In 1904 an attempt was made to repeat the investigations of Johannsen on the inheritance of seed-weights in beans, because his results were thought to be in disaccord with Galton's law of inheritance. The choice of Burpee's bush lima bean for the investigation was unfortunate, because it does not maintain a strict bush form, and

the work planned with this variety was abandoned. Occasion was taken, however, to point out in a paper presented before Section G, American Association for the Advancement of Science, December 30, 1904, and afterward published in Torreya, that Johannsen's results are in exact agreement with Galton's law, instead of being contrary to it. The importance of Johannsen's results, however interpreted, make it a matter of some regret that they were not elaborated by more approved statistical methods. As a corollary to his conclusions, every change in bean-weights capable of being segregated by selection within the individual pure line is of the nature of a mutation. To satisfy the desire for a more appropriate elaboration and to investigate the occurrence and behavior of these minor mutations, the study is being repeated this year with Henderson's bush limas. This variety has proved highly satisfactory, as it forms a bush of moderate size and blooms and fruits well when inclosed in bags of mosquito netting, this means being adopted to insure the purity of the hereditary lines.

The transmissibility of certain abnormalities has been tested with the following results: Of eleven specimens of *Rudbeckia hirta*, the entire progeny of a strongly fasciated individual, only one showed evidence of fasciation, but the offspring of a fasciated *Ambrosia artemisiæfolia* had slight fasciations in 8 of the 15 specimens. Compound spikes of *Plantago lanceolata* were transmitted, fully developed, to one of 26 offspring. Six of the other specimens showed abnormalities which may be related in character to the compound spike. These consisted in the occasional production of scapes bearing one or several leaves, or even a well-formed rosette, while axillary to these leaves arose scapes terminated by single unbranched spikes. *Plantago major* did not transmit in a single well-marked case, in a progeny of more than 100 specimens, a rosette of leaves about the base of the flower-bearing portion of the scapes. The possibility is not excluded, however, in this case, nor in other cases in which a parental character is wanting in the offspring, that the young are heterozygotes in which the character in question is recessive. This point can only be determined by the study of a second generation.

In the common garden form of *Helianthus annuus*, known as the Russian sunflower, two characters have been chosen for the study of inheritance. One of these characters, the greater or less degree of bifission of the leaves at the second node above the cotyledons, is obviously a progressive character, while the other character—the branching habit—is, at least in a certain sense, atavistic or degressive. Both of these characters prove to be rather strongly inherited,

though to what extent this will be true when both parents are bearers of the characters in question must be determined by further investigation, as the pollen parent of this year's progeny is in each case unknown.

Hybridizations made last year between different varieties of beans give excellent material illustrative of one of Mendel's laws of inheritance, in that all pigments are dominant over white and in each case the darker pigment is dominant over the lighter. In every case the reciprocals are equal. Crosses with the "White Flageolet" give beautiful examples of *nova* and illustrate the nature of latency. The offspring from crosses between this variety and any pigmented bean, whether yellow, brown, or black, invariably bear purple-mottled seeds in the first hybrid generation.

Hybridizations have been attempted this year between varieties or species of *Lychnis*, *Eschscholtzia*, *Verbascum*, *Helianthus*, etc.

A study into the significance of stages in the development of *Sium cicutæfolium* was completed and published as No. 3 of the Papers of the Station for Experimental Evolution.

Most of the specimens collected during 1904 for the herbarium have been mounted and arranged according to Engler & Prantl's system of classification. These include: The Flora of Cold Spring Harbor, L. I., 190 specimens; seedling and juvenile forms, 3 specimens; pedigreed plants, 72 specimens; total, 265 specimens.

Among these the following have not been hitherto recorded from Long Island: *Panicum tennesseense*, *Agrostis scribneriana*, *Scirpus paludosus*, *Carex scoparia condensa*, *Rosa micrantha*, *Onagra oakesiana*, *Xanthium commune*, *Aster herveyi*, *A. salicifolius*, and *A. lowrieanus*.

The following recorded for other parts of Long Island have not been mentioned for Cold Spring Harbor: *Ammophila arenaria*, *Gyrostachys simplex*, *rifolium Thybridum*, *Hieracium marianum*, *Bidens cernua*, *Solidago rugosa*, and *S. juncea*.

The number of specimens added to the herbarium this year is estimated at 600.

REPORT OF F. E. LUTZ.

The biometrical and experimental work with *Gryllus* has been carried on throughout the year. From the matings made during September, 1904, 118 adult offspring were reared. There was a considerable mortality in the early stages. It is hoped this will be, to a great extent, avoided in future generations. All these adults, with the exception of three badly deformed ones, have been mated and a large quantity of eggs has already been obtained. These matings are, for the most part, *inter se*, but a number of the pedigree crickets have been

mated with individuals obtained (as nymphs, and reared with the sexes separated) in nature. Other matings have been made from material from various localities and representing several species. While the eggs of most of these are due to hatch in the spring of 1906, it is hoped that they may be hastened somewhat. The characters whose inheritance and variation are being studied in this connection are very diverse, including alternative and blending, integral and graduated.

As opportunity offered, experiments with other insects have been tried and a number of them are still being continued. These are chiefly concerned with the variations produced by changed environment and the inheritance, if any, of such variations. The principal insects used in these studies are *Isia isabella*, *Spilosoma virginica*, and *Estigmene acrea* among the Lepidoptera, and *Lena lapponica*, *L. scripta*, *Gastroidea polygoma*, *G. cyanea*, *Crioceris asparagi*, *C. 12-punctata*, and *Labioderma clivicollis* among the Coleoptera.

The collection of local meteorological data is of great importance to the station. A summary is given at pages 105–106.

REPORT OF ANNE M. LUTZ.

The work of the year has been divided between the duties attendant upon the secretary of the station and the search for the interpretation of the laws of heredity in the germ glands of various plants and animals. A considerable number of species of animals have been collected, chiefly insects, and their germ glands sectioned and mounted secondarily for a reference cabinet, but primarily with the view of discovering suitable material for hybridization experiments. Recently the collection has been limited chiefly to two families of Coleoptera, Coccinellidæ and Chrysomelidæ, and as many representative species of each obtained as possible. Whenever obtainable, the late larvæ and pupæ have been selected in preference to adults. A fairly representative collection has been secured for the study of problems in mind.

Progress has been made on the solution of the problem of the infertility of the reciprocal crosses of long and short styled *Fagopyrum fagopyrum*. Work on the long crossed with the short has been completed, but the reciprocal, involving more delicate cytological details, was found to require better fixation than was obtained in the original lot, and a crop is now growing for this purpose. Fertilization in this case will be controlled within doors, and some of the dangers of error eliminated.

Early in July two species of *Gastroidea*, namely *G. cyanea* and *G. polygoni*, were found feeding together and freely interbreeding.

The colors of thorax, abdomen, and elytra were so strikingly different in the two species that they seemed to be favorable material for hybridization. Before going into the detailed study of the germ glands of the two species, it seemed advisable first to determine the fertility of the supposed hybrid eggs. Several generations of each species were first bred true, to be certain of parentage, and twelve or fifteen pairs of adults were hybridized reciprocally. They mated freely, and thousands of eggs were deposited, but no larvæ hatched. Control pairs of straight matings of each species were kept under observation at the same time, and while it was noted that fewer eggs were deposited than by the first generation, and a smaller percentage of eggs hatched, large numbers of larvæ were continually hatching and feeding. The experiment was abandoned for the present season, but will probably be undertaken by Mr. Lutz or myself on a larger scale next summer.

REPORT OF ROSWELL H. JOHNSON.

Since my work at the station began July 18, 1905, this report must be one of progress rather than results. Owing to the lack of running salt water, I have postponed the proposed work upon the shrimp and devoted myself wholly to the investigation of the lady beetles. These beetles offer the following advantages as material for the study of the method of evolution :

1. They are in general decidedly variable in color pattern in each locality, and in many species show geographical races.

2. There are many "varieties" in some species, ranging from mere "aberrations" to forms over which systematists are in disagreement as to their recognition as species.

3. There are some species whose relationships seem evident and which have doubtless only relatively recently become segregated.

4. Some species, I have found, are readily modified by change in environment.

5. The generations are short, and some species at least may be bred under glass in winter.

6. Being easily recognized and collected by correspondents, extensive collections are possible. This is especially true of some species which are gregarious.

Since they may be fed upon plant-lice or scale insects, I began a collection and catalogue of the local aphids and determined the best host-plants for use indoors and in the garden. The most suitable plants have been propagated in the breeding-room, that there may be an adequate supply of food when the aphids out of doors disappear for the season. I am now feeding many pairs from California, the Rocky

Mountains, and New York, awaiting further egg-laying, and have already 18 fraternities of larvæ from these pairs. The larvæ require from two weeks to a month from egg to pupa. About five days are required for the egg and pupa stage, respectively.

The questions to be answered by the earlier generations are :

1. To what extent are the various color patterns inheritable ? and

2. Does rearing under local and indoor conditions modify them from the ancestral pattern ?

With these questions answered I shall undertake hybridization, selection, and modification experiments.

Since many larvæ of one species could be collected this summer, I began a series of experiments upon modification by various changes in the environment. Some factors seemed relatively impotent, but temperature was effective in producing marked changes paralleling observed geographical races. These changes affected certain parts of the pattern only, thus producing more than a change in the amount of melanism.

Before taking up my work here I had collected large series of one species, *Hippodamia convergens*, from diverse regions, and I am now extending that collection by exchange and purchase. I find that some alleged species are connected by many intergrades, as might be expected. The various lines of orthogenetic variation in the different regions seems more remarkable. As a proper introduction to my experimental results in *Hippodamia*, I propose to submit in April a paper on " Orthogenetic variation in *Hippodamia convergens*."

REPORT OF DR. W. J. MOENKHAUS.

During the summer of 1904 material was collected at Woods Hole and Cold Spring Harbor for the study of the behavior of the maternal and paternal chromosomes in hybrid fishes. Early stages of the following crosses were preserved :

1. Fundulus heteroclitus × F. diaphanus.
2. Fundulus heteroclitus × F. majalis.
3. Fundulus heteroclitus × Tautogolabrus adspersus.
4. Fundulus heteroclitus × Stenotomus chrysops.
5. Fundulus heteroclitus × Gasterosteus bispinosus.

Crosses 2 and 5 have been worked up without results ; 3 and 4 have not yet been studied, but I am hopeful that they may yield some important thing in the chromosomal behavior in early hybrid development.

Considerable work was done with the crosses between *Fundulus heteroclitus* and *Fundulus diaphanus*. In the cytological work on these I had the coöperation of Miss Anne M. Lutz. It was hoped

that the hybrids between these two species might be successfully reared to maturity, so that the behavior of the maternal and paternal chromosomes during sex-cell formation could be studied. About 4,000 hybrids (*Fundulus heteroclitus* × *F. diaphanus*) were hatched. On August 16, 1904, about 1,500 of these were successfully transported in Mason jars to Bloomington, Indiana. These were kept alive until September 20, 1904, when the last died. It was found impossible, under the adverse water conditions at my disposal, to keep down the attack of fungus.

A careful study of the germ glands of the three species of *Fundulus* has convinced me that fishes are unfavorable forms for the study of chromosomes in sex cells. This fact also determined me not to attempt the cross between the whitefish and lake herring which I had planned.

A portion of my time during the summer of 1905 was devoted to the problem of the variability of the sex ratios and their modification through selective breeding. The forms experimented upon are three species of flies. The experiments are not far enough along to permit of a statement of the results. I have at present (October 15, 1905) the data on 14 families. From these I isolated 2,378 eggs. The number of eggs hatched, the number that emerged, and the sex ratios of each of the families were determined. This is an exceedingly laborious process, but my experience during the past winter has shown that in selective breeding for one sex or the other it is essential that account be taken of the mortality during the life history.

CLIMATIC DATA.

The first frost of 1904–05 occurred October 16, 1904. The first killing frost was on the 27th of the same month. The last freezing temperature was on May 2, 1905. The last frost was May 2, with a close approach to frost (37°) on May 21. The first frost in the autumn of 1905 was on October 8; the first killing frost October 31. The first snow fell November 25, 1904. The ground was covered with snow December 8 to January 19, and January 25 to February 28. The last snow flurry was on April 17.

PRECIPITATION BY MONTHS.

Time.	Total amount.	Snowfall.	Time.	Total amount.	Snowfall.
1904.	*Inches.*	*Inches.*	1905.	*Inches.*	*Inches.*
November	2.31	0.3	June	3.81	0.0
December	3.98	33.0	July	3.42	0.0
1905.			August	6.06	0.0
January	2.76	6.0	September	5.76	0.0
February	2.69	4.5	October	2.64	0.0
March	4.11	1.0			
April	3.25	Trace.	Total	42.00	44.8
May	1.31	0.0			

TEMPERATURE AT COLD SPRING HARBOR, BY WEEKS.

1905.	Maximum. Actual.	Maximum. Mean.	Minimum. Actual.	Minimum. Mean.	Mean.*	Soil at 2 feet.†	Sensible at 5 p. m.
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*		
Feb. 5–Feb. 11	31	27.4	—5	12.9	20.2	....	....
Feb. 12–Feb. 18	40	29.4	0	8.3	18.9	....	....
Feb. 19–Feb. 25	36	32.7	+9	16.6	24.7	....	....
Feb 26–Mar. 4	39	35.1	10	15.3	25.2	....	....
Mar. 5–Mar. 11	47	39.3	9	21.6	30.5	....	....
Mar. 12–Mar. 18	63	42.4	16	22.7	32.6	....	....
Mar. 19–Mar. 25	55	47.7	25	32.1	39.9	....	40.3
Mar. 26–April 1	74	67.1	29	35.6	51.4	....	51.0
April 2–April 8	58	53.3	24	30.9	42.1	....	43.1
April 9–April 15	69	60.9	25	36.9	48.9	....	48.9
April 16–April 22	68	56.9	23	33.7	45.3	....	44.1
April 23–April 29	70	62.4	29	39.4	50.9	49.5	52.6
April 30–May 6	77	66.9	31	44.1	55.5	51.0	51.5
May 7–May 13	84	71.4	41	49.1	60.3	54.5	58.0
May 14–May 20	76	67.1	45	50.1	58.6	55.5	49.3
May 21–May 27	76	71.1	37	46.4	58.8	57.0	60.0
May 28–June 3	80	72.3	47	53.9	63.1	61.0	62.5
June 4–June 10	82	74.0	43	50.4	62.2	60.5	58.8
June 11–June 17	85	78.6	58	60.0	69.3	62.5	69.6
June 18–June 24	87	75.9	54	61.6	68.8	64.5	66.4
June 25–July 1	88	80.1	51	56.9	68.5	65.0	68.0
July 2–July 8	86	81.1	60	64.1	72.6	66.5	71.7
July 9–July 15	90	87.9	66	69.4	78.7	70.5	77.7
July 16–July 22	98	89.9	55	63.7	76.8	72.0	78.0
July 23–July 29	84	79.7	53	58.4	69.1	69.5	69.1
July 30–Aug. 5	84	79.9	54	61.1	70.5	69.0	70.1
Aug 6–Aug. 12	88	82.4	61	67.4	74.9	70.0	75.4
Aug. 13–Aug. 19	83	74.1	47	57.9	66.0	69.0	63.9
Aug. 20–Aug. 26	86	80.3	52	61.6	71.0	68.0	70.6
Aug. 27–Sept. 2	78	73.4	50	57.0	65.2	67.0	66.1
Sept. 3–Sept. 9	77	74.6	51	58.4	66.5	67.0	66.9
Sept. 10–Sept. 16	80	72.1	39	51.7	61.9	66.0	62.6
Sept. 17–Sept. 23	81	74.7	57	60.1	67.4	66.0	67.3
Sept. 24–Sept. 30	85	71.4	36	46.4	58.9	63.5	58.9

* From maxima and minima. † Averages given to nearest half degree.

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NOTE So far as possible this list has been checked by the authors, but in some parts it is doubtless incomplete Necessary additions will appear in the next report.

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BIOLOGY, MARINE.

MARINE BIOLOGICAL LABORATORY AT TORTUGAS, FLORIDA *

BY A. G. MAYER, DIRECTOR

On October 15, 1904, the laboratory yacht *Physalia* started southward from New York under command of the director. The yacht's behavior in a storm off Cape Cod had demonstrated the necessity for lightening her keel and for after ballast; and consequently the iron keel had been replaced by one of oak, shod with iron, and a large fresh-water tank was placed in the after hold. The advantages of these changes were apparent in the hurricane of November 13, 1904, when the *Physalia* survived with only the loss of her jib, while all of the vessels in her neighborhood were driven ashore.

The course southward lay out along the New Jersey coast, up Delaware Bay, through the Delaware and Chesapeake Canal, through Chesapeake Bay, the Dismal Swamp Canal, Pamlico Sound, out at Beaufort, North Carolina, stopping at Bogue Inlet, Winyah Bay, and Charleston, then through inland passages to Beaufort, South Carolina, then seaward to Sapello Sound and Brunswick, Georgia, inland to Fernandina, seaward to St. Johns River, St. Augustine, and finally to Miami, Florida, where the yacht arrived in good order on January 23, 1905.

Surface hauls were made with the tow nets upon all possible occasions in order to take advantage of the opportunity afforded for the determination of the relative abundance and the difference in character between the pelagic animals of bays and inclosed waters such as Long Island Sound, Delaware and Chesapeake bays, Pamlico Sound, etc., and the open ocean. Colored drawings were made from life of all new or interesting Medusæ, Siphonophoræ, and Ctenophoræ.

It may be briefly stated that while the pelagic fauna of bays and inclosed waters is rich in individuals, it is poor in variety of species when compared with the open ocean. Certain forms such as the ctenophore *Mnemiopsis* or the hydromedusa *Glossocodon tenuirostris*, are exceedingly abundant in inclosed areas, even in brackish water, while others, such as *Nemopsis bachei,* thrive only near the mouths of bays, where the sea-water enters quite freely. The vast majority of pelagic animals that are carried into bays and inclosed waters are quickly killed, and are found in a more and more damaged condi-

* Grant No. 219 $15,700. (For first report see Year Book No. 3, pp. 50–54

PLATE 5.

VIEW OF LABORATORY BUILDINGS AT TORTUGAS FROM THE NORTH, SHOWING THE DOCK AND AQUARIUM.

tion as we go inward from the ocean. This applies especially to the Siphonophoræ, Tunicates, and Sagittæ so characteristic of the ocean.

Our richest hauls were made in or near Willoughby Harbor, Virginia, on Hampton Roads, near the mouth of Chesapeake Bay. This harbor is perfectly protected and very accessible from Norfolk or Old Point Comfort. The ocean-water enters freely, bringing a great variety of creatures in good condition, while the inland waters themselves supply a rich contingent to the fauna. An *Amphioxus* is abundant along the shores. No better situation could be found for a marine laboratory, combining both inland water and open-sea features.

Beaufort, North Carolina, affords the richest collecting-ground for mollusks we met with on the entire voyage, and it is a pleasure to express our gratitude to the authorities of the laboratory of the U. S. Bureau of Fisheries, who allowed the writer the privilege of studying the rare Medusæ in the laboratory collection. A remarkably large number of gorgonians, corals, and mollusks, characteristic of tropical regions, appear at Beaufort in the northern limit of their range.

We met with the most northerly coquina at Fort Fisher, Cape Fear, North Carolina. This consisted of a large ledge on the sea-beach, the rock being composed of a mixture of *Astrangia,* broken shells, and siliceous sand agglutinated by calcareous matter into a readily friable rock.

The most northerly grove of palmetto palms appears near the outer sea-beach at the southern extremity of Smith Island, Cape Fear, North Carolina.

The most marked change in the pelagic fauna appears upon rounding Cape Cod, many arctic forms being found only to the northward, and southern forms to the southward of this point. Great Peconic Bay, Long Island, teems with southern forms in September, reminding one of the fauna of Charleston Harbor, South Carolina.

Only a few creatures may be called characteristic of the offshore ocean waters between Sandy Hook and Cape Canaveral, Florida. The most conspicuous of these are the large scyphomedusæ *Cyanea versicolor* and *Stomolophus meleagris.*

South of Cape Canaveral we find a host of tropical forms appearing in perfect condition, although these are frequently found in a more or less damaged state far to the northward, being sometimes drifted upon the southern coast of Massachusetts, south of Cape Cod.

Upon arriving at Miami an inspection of the yacht showed that the copper bottom had caused serious corrosion of the iron parts of the rudder and centerboard, and these essential parts were replaced by a rudder stock, port, and shoe, and centerboard pin of brass. It was deemed unnecessary to replace the heavy steel-wire centerboard pennant, but this fancied security proved a delusion, for it broke off Key West, and the yacht, drawing 18 feet instead of 5, had to be brought back to harbor in the face of a storm. Hauling out and a day's work, however, repaired the damage in a way to prevent the possible recurrence of such an accident. The yacht was thoroughly overhauled and painted while at Miami.

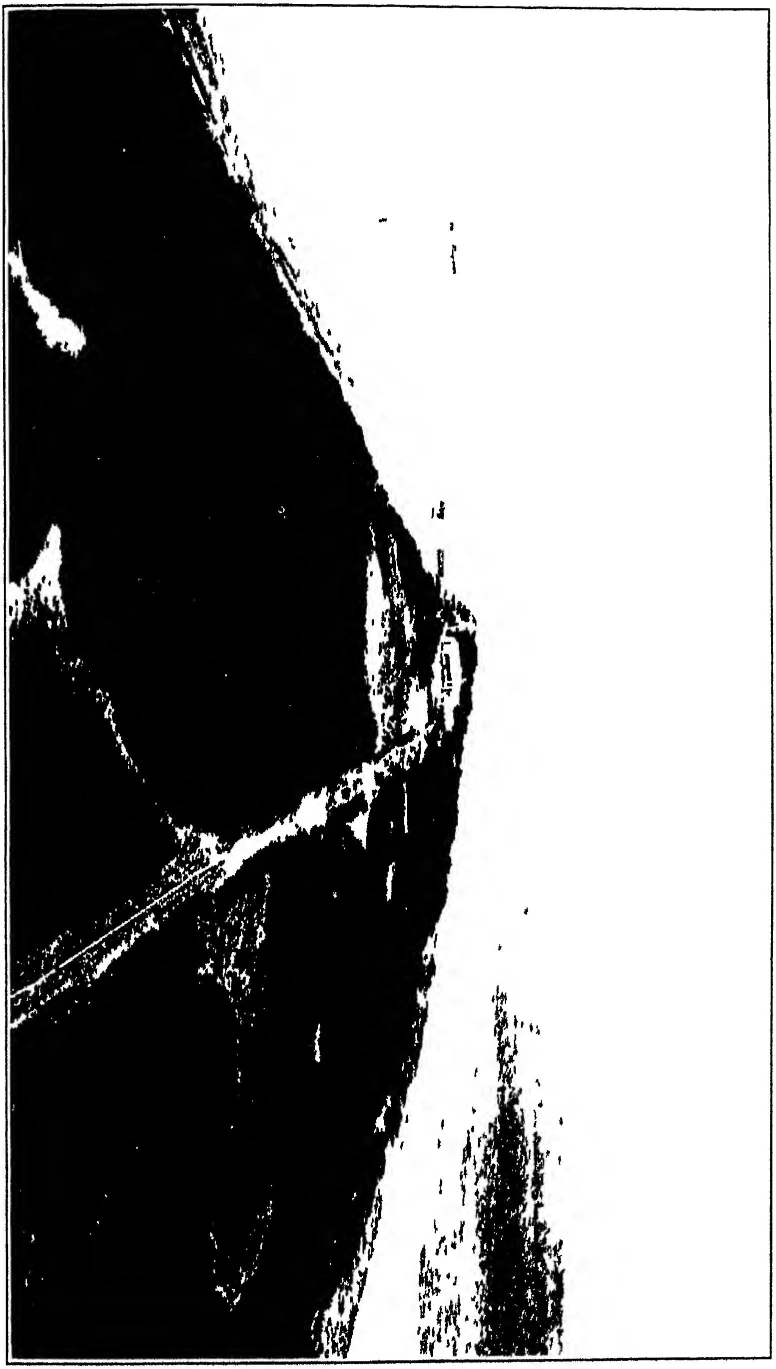
A 22-foot 4-horsepower Swampscott dory, capable of making 9 knots speed, was purchased during the year, and proved to be very useful. It enabled us to make daily surface hauls and dredgings in the vicinity of the Tortugas under peculiarly advantageous conditions. Several hundred miles of surface tows were carried out by this vessel alone. The *Physalia* proved invaluable in going out into the Gulf Stream, for dredging in considerable depths, for intermediate towing in the open sea, and for long cruises.

During the year the laboratory buildings on Loggerhead Key, Tortugas, have been thoroughly equipped, so that at present they afford advantages for research in marine zoölogy unequaled anywhere else in the tropical world.

A dock was run out 80 feet from the beach, giving a draft of over 5 feet at low tide, and thus permitting the *Physalia* to approach it at any time. The timbers of this dock were especially braced to resist a possible hurricane, and the wooden piles covered with copper sheathing to withstand the attacks of the teredo. Connected with the dock, and on its southern side, a kitchen was constructed, having 16 by 16 feet floor space, and elevated 8 feet above high tide upon wooden piles. The advantages of such a kitchen in the tropics are obvious from the ease with which it may be maintained in a cleanly condition, and it was noticeable that flies, roaches, and other pests characteristic of hot countries, were absent. All refuse from the kitchen was daily towed out to sea and disposed of.

For similar reasons modern plumbing was introduced, thus obviating the possibility of the introduction of typhoid fever, etc. Hygienic precautions are absolutely necessary if northern men, unaccustomed to a hot, moist climate, are to maintain good health while engaged in the confining and arduous labor of investigation. It is gratifying to be able to state that no zymotic diseases were contracted

To face page 110



THE NORTH END OF LOGGERHEAD KEY SEEN FROM THE TOP OF THE LIGHT-HOUSE. SHOWING THE LABORATORY AND ITS HARBOR 1,100 FEET DISTANT.

by anyone at the laboratory, although one investigator suffered in this respect in Tampa or Key West before arriving at the laboratory. We have to contend with the fact that investigators come to the laboratory much depleted, physically, from the excessive labor and confinement of their college duties, and it is essential that conditions at Tortugas should preclude the possibility of the contraction of any tropical diseases. Fortunately there are no breeding-places for mosquitoes on Loggerhead Key, although *Culex* is occasionally blown upon the island from the Florida Keys, 40 miles distant.

North of the dock and opposite the kitchen, a well-ventilated, cool, aquarium-laboratory was constructed. This has a floor space of 20 by 20 feet, and contains two tanks, a pump for salt water, and other conveniences for maintaining marine animals in conditions approaching those of nature. A cool, well-ventilated aquarium, with facilities for altering the intensity of light, is indispensable to a laboratory affording unrivaled facilities for physiological and embryological studies. The ocean-water at Tortugas is warmer than that of the aquarium; hence animals may be maintained at their normal temperature. This advantage will be appreciated by all who have been discouraged by the unavoidably high temperature of small aquaria in northern laboratories. Suffice it to say one may maintain medusæ, worms, crustacea, etc., in excellent health at Tortugas, in aquaria, for months.

A considerable quantity of fresh water is necessary in a region where it may not rain for a month at a time, and where wells can not be made. Accordingly two galvanized-iron cisterns capable of holding 1,326 cubic feet of water were installed, and also a wind-mill and salt-water tank to economize the use of fresh water, and to supply the laboratory and water closets.

Laboratory tables for microscopic work must be independent of the building so as to avoid the communication of vibrations one to the other. This was accomplished by driving the legs of the tables firmly into the ground through holes in the floor, and not permitting them to touch the building at any point. The eight tables in the main laboratory building are L-shaped, one arm of the L being at the right hand of the investigator and the other facing the northern light.

The original composition material used for roofing the laboratory buildings began to deteriorate in the hot, moist climate and to develop leaks. The buildings were therefore covered with heavy canvas, painted. This does not interfere with the portable character of the buildings, and while expensive, gives a cool, efficient roofing capable

of maintaining the interior dry even in the most severe tropical showers.

A subterranean oil-house, 16 by 20 feet, was made in order to store the large amount of naphtha, oil, alcohol, and other inflammable substances, and maintain them at a low temperature and in a situation where a fire would not spread to the laboratory buildings.

The laboratory buildings were also repainted, two more sleeping rooms and a dark room constructed, and the roofs braced with brackets to strengthen their resistance to high winds.

Six floating live-cars were made in the shape of scows, 6 by 3 by 2 feet deep. These were floated by copper cylinders, and their bottoms were provided with openings covered with gratings. Marine animals could be maintained in good condition for months in these live-cars when they were anchored under the shade of the dock so as to avoid the extreme heat of the sun.

Buoys were set out to mark the passages across the coral reefs, thus enabling us to enter or leave our harbor at any time of the day. Everyone who has navigated in a coral-reef region knows the danger of attempting to cross a coral reef in the face of the sun, and our buoys obviated this difficulty.

One hundred cocoanut palms, and a number of azalias, date palms, rubber trees, bananas, and ornamental cacti were set out in order to render the glare of the coral sands less severe, to beautify the grounds, and to provide protection to the buildings from hurricanes.

The property now consists of the two main portable buildings, the kitchen, aquarium, dock, oil-house, out-house, wind-mill, and three cisterns; while the vessels are the 60-foot 20-horsepower ketch *Physalia,* the 22-foot 4-horsepower launch, the 15-foot 3/4-horsepower launch, and a row boat.

The laboratory employees during the actively open season, from April to August, consisted of two sailors, an engineer, a steward, a laboratory servant, and a man-of-all-work. The large amount of constructive work of the past year rendered it necessary to employ six additional workmen from February 2 to April 29, and three from February 2 to July 27.

The essential parts of the laboratory were completed in the order of their importance, and only the shipways remains to be set up The parts of the shipways are, however, assembled, advantage being taken of the necessity for hiring a schooner to transport this heavy material to the Tortugas.

With the exception of a small amount of glassware and reagents, all of the laboratory apparatus and furniture was purchased during the present year. The laboratory is equipped with a very complete supply of chemicals, photographic apparatus, a delicate balance, glassware, aquaria, and books of general reference. The furniture consists of light chairs, tables, and lounges, and the beds are swung from the roof-beams, thus avoiding ants and other tropical pests.

The difficulties of maintaining an efficient laboratory at Tortugas are considerable, but by no means insurmountable or of a character to interfere with the success of the most elaborate investigations. Its base of supplies, Key West, is 70 miles away, and is itself 140 miles from the mainland. This increases the cost of all ordinary supplies, and renders it desirable to purchase in bulk in the north as far as may be possible. All ordinary needs must be appreciated and provided for a long time in advance. At least ten days must elapse before anything can be ordered by mail and delivered from New York. Labor is expensive, and if not carefully selected, inefficient, and high wages must be paid in order that men may remain content to labor continuously in so isolated a region as the Tortugas.

To offset these disadvantages the Tortugas affords a situation securely isolated from tropical infections. The pelagic fauna is the richest in the Atlantic, and the coral reefs provide a varied fauna. The station provides unrivaled facilities for researches in physiology, regeneration, embryology, behavior, and life histories, and for all studies requiring that animals be maintained alive for considerable periods. At no station in the world is the ocean water purer or the fauna less disturbed by local fisheries. In the opinion of the director advantage should be taken of these conditions, and the work of the laboratory should be aimed in the direction enumerated above rather than to the amassing of collections for systematic study.

THE SCIENTIFIC WORK OF THE LABORATORY.

Invitations to prosecute researches at the laboratory were extended to a number of biologists distinguished for their investigations in science, and from among the number the following gentlemen accepted and carried out investigations at the Tortugas: Profs. E. G. Conklin, from April 21 to May 13; H. S. Jennings from June 2 to 22; William K. Brooks and his assistant, Mr. Kellner, from June 16 to July 19; R. P. Cowles from June 20 to July 26; Jacob Reighard and H. F. Perkins from June 23 to July 26. Mr. Davenport Hooker, of Yale University, served as scientific collector for the laboratory during June and July.

Prof. William K. Brooks studied the development of *Salpa* and *Doliolum*, especially the asexual budding of these forms, and we are informed that he obtained sufficient material to enable him to complete his extensive memoir upon the subject, which has been in preparation for some years. Salpæ were exceedingly abundant during April and May, but at the time of Professor Brooks's visit they were relatively rare, and it is to be regretted that he was unable to obtain a greater number of specimens. His assistant, Mr. Kellner, made excellent drawings of all new or interesting forms.

Preliminary Report of W. K. Brooks, on the Metamorphosis of Alpheus heterochetes.

In 1881 Packard studied the metamorphosis of *Alpheus heterochetes* at Key West, and showed that its development is much abridged and very slightly different from that of *A. minus* and other species of the genus. At Key West *A. heterochetes* lives within the tubes of sponges.

In 1884 I found at Beaufort that the metamorphosis of this species is nearly complete, and very different from that of *A. minus*. At Beaufort the species is not parasitic. I had not then read Packard's paper, but as my other observations were made with care, and as every stage of the development of the larva was drawn, and as my results seemed to be irreconcilable with his, I seemed forced to decide that he had made some mistake.

In 1886 *A. heterochetes* was found in abundance in the Bahama Islands, living as a parasite in the tubes of sponges. The larvæ were studied and drawn at every stage of their metamorphosis, which proved to be even more abridged than that which Packard studied at Key West, and like that which is common to the genus as illustrated by that of *A. minus* and other common species.

These observations indicate that Packard's account was correct, and that *A. heterochetes* has one life history at Beaufort, another at Key West, and a third in the Bahamas; that the life history in the Bahamas is like that which is characteristic of the genus; the life history of Beaufort very different from that of other species of *Alpheus*, and that at Key West midway between that of the Beaufort specimens and that of the Bahama specimens.

While our observations in the Bahamas thus indicate that Packard's account is correct, a verification of his observations at Key West is still to be desired, and I was pleased to find larvæ of *A. heterochetes* at the Carnegie Laboratory in the Tortugas last summer, and to show that the life history of this species there, only a short distance from Key West, is as Packard describes it, and transitional between the life history at Beaufort and that in the Bahamas.

Prof. Edwin G. Conklin discovered that the substance of the egg of the scyphomedusa *Linerges* is differentiated into concentric layers in a manner comparable to the condition previously demonstrated by him in mollusks and tunicates. The eggs of the highest and of the lowest metazoans are therefore comparable even in their

minute details of structure. Professor Conklin's discovery is one of wide-reaching import, and it is but fitting that his masterly researches of the past years should thus have led him to the revelation of a fundamental law of zoölogy.

Preliminary Report of E. G. Conklin upon the Structure of the Egg of Linerges, etc.

I joined the yacht *Physalia* at Key West on April 21, and during my stay on the yacht and at the Carnegie station at Tortugas, from April 22 to May 13, 1905, I made, in addition to many general observations on the rich and varied fauna of that region, detailed observations on the early development of a scyphomedusa, *Linerges mercurius,* and a study of two remarkable actinian larvæ which are quite unlike any other larvæ ever yet described.

In *Linerges* the cleavage of the egg is total and regular and a typical invaginate gastrula is formed which, by closure of the blastopore and elongation of the larvæ, gives rise to the usual planula. The polarity of the egg bears a definite relation to the polarity of the larvæ, the animal pole of the former corresponding to the apical pole of the latter. Furthermore, the substance of the egg is differentiated into at least three concentric layers, which are recognizable at every stage from the unsegmented egg to the planula. These layers correspond in a general way to the ectoderm, mesoderm, and endoderm of the larva. Owing to the sudden disappearance of these jellyfish I was unable to test experimentally the potency of these different layers of the egg. It seems probable, however, that the observed totipotence of fragments of Medusa eggs (Maas, Zoja) is due not to the lack of differentiation in the egg substance but rather to the concentric localization of such different substances as are visible in *Linerges.*

The two types of actinian larvæ which I studied are each characterized by the possession of a membranella, or locomotor organ, composed of fused cilia. In one type this membranella is circular in form, surrounding the body about one-third of the distance from the oral to the aboral pole. In the other type the membranella is longitudinal, running along the ventral side from the oral pole two-thirds of the way to the aboral pole. These larvæ have the mesenteries well formed, but show no trace of tentacles.

Dr. R. P. Cowles carried out an elaborate series of studies upon the reactions and behavior of a number of species of Ophiurans and of the ghost crab, *Ocypoda arenaria.* Dr. Cowles presents the following preliminary report:

Preliminry Report of R. P. Cowles upon the Behavior of Ocypoda arenaria.

Ocypoda arenaria, commonly known as the sand crab or ghost crab, is found in great abundance on Loggerhead Key, and its burrows occur generally along a belt extending from the shore-line to 20 or 30 feet from it. These usually consist of a main passage opening to the exterior and extending down into the sand at an angle of about 45 degrees, with a more or less vertical

passage branching off from it and sometimes communicating with the exterior. The latter passage is used only for escape when the crab is pursued by an enemy. In digging its burrow *Ocypoda* carries the sand out with its legs, holding them so that they make a sort of basket, and upon reaching the surface the load is disposed of by a quick movement of the legs, which may throw the sand for a distance of a foot or more. Molting takes place during the spring and early summer, and probably occurs at the bottom of the deep burrows.

The males are somewhat larger than the females, and on account of their fighting are more scarred. The breeding season probably extends throughout the summer and occurs just after molting.

Ocypoda feeds both during the day and night, and is a scavenger; but small live fish are also eaten with apparent relish. While the olfactory sense to some extent guides these crabs to their food, the eyes, feeling, and taste seem to be the principal factors. Any small object dropped upon the sand within 4 or 5 feet of them when the observer is hidden is usually immediately seized for food. In this case it is not the appearance that suggests it is food, but the fact that the object has moved.

On Loggerhead Key, *Ocypoda* seems to have but two enemies, namely, the gray snapper and the land crab. The birds do not molest it, and there are no mammals excepting man on the island.

While Ocypodæ frequently fight among themselves, fatalities do not generally occur, and it is only seldom that an individual is found with one of its chelæ missing. They often attack and kill the land crab, which is protected with a much harder shell than its own. The older Ocypodæ nearly always have fractured ambulatory appendages, the result of pinches received while fighting.

Often, when an individual is surprised, so that it runs a danger in trying to get back to its burrow, it will settle down in a little hollow and partly cover itself with sand, usually leaving the eyes exposed. Occasionally the young *Ocypoda* will lie flat upon the sand, remaining perfectly still and allow man to approach within a foot or two. The adults are not conspicuous when observed at a distance of 30 or 40 feet, but when 8 or 10 feet away they are easily seen. In the young, however, the color of the carapace is chalky gray, making them almost indistinguishable from the sand when the observer is a few feet away.

Ocypoda travels sideways with surprising speed, and is able to move forward almost as fast. It can walk backwards with difficulty, but when a quick movement in this direction is necessary it usually jumps.

While *Ocypodae* live well submerged in sea-water, they are unable to exist long without it. The hot sun shining directly upon them in confinement will soon cause death. They do not go into the ocean to feed, but only to replenish the water in their gill chambers, or to escape from enemies, and in no case do they venture into deep water. It seems to be necessary for the young to change the water in the gill chambers more frequently than for the adults, and their burrows are made correspondingly closer to the water-line.

Ocypoda is usually able to return to its burrow quickly and with considerable accuracy from a distance of 15 or 20 feet. While the eyes are probably a factor contributing to this accuracy, the sensitive ambulatory appendages undoubtedly aid by the sense of touch.

The observations made on *Ocypoda* do not indicate that it sees in the sense that man does, but that it only reacts to different intensities of light. It detects the approach of man much more easily when the sun shines than when it is cloudy, and also more easily in the middle of the day than in the early morning or evening.

There occurs a compensatory movement of the eye-stalks when the normal equilibrium of an individual is disturbed. Painting the eyes with shellac and lampblack causes individuals to become more quiet and to sit with the body closer to the ground, as has been observed by Prentiss. When in this condition they seem to be much more sensitive to vibrations. Cutting off the eyes produces the same effect, but such operations do not prevent them from feeding when food is put within reach of their chelæ. The eyes are least sensitive when the light stimuli come from above; in fact, when the observer is directly overhead they pay no attention to his movements. Experiments performed so far do not indicate that *Ocypoda* is more sensitive to one color than to another.

The olfactory sense is developed to some extent, but is not keen, and such substances as carbon bisulphide, formaldehyde, and ammonia apparently do not affect the organs of smell to any considerable degree.

The otocysts are undoubtedly equilibrating organs, and their removal produces a decided disturbance in the equilibrium of *Ocypoda,* both when it is on land and when submerged in water. There is no evidence that these organs have an auditory function, or that this crab reacts in any way to sound-waves; however, no experiments have been performed to determine if sounds have any effect on other reflexes.

A so-called "stridulating ridge" is present on the large chela in both male and female. It consists of a ridge of tubercles extending across the inner surface of the propodite, and is placed so that when the forceps are bent close to the basal segment the ridge comes in contact with a projection on the former. While the writer has never heard any sound produced by this apparatus, he has, on several occasions, seen fighting individuals moving the forceps back and forth with great speed against the basal segment.

Ocypoda is quite sensitive to vibrations transmitted to any solid object with which it is in contact, and it reacts sometimes by jumping, but more frequently by a sudden lowering of the eye-stalks. It does not seem to react to vibrations of air or water.

Experiments devised to determine whether *Ocypoda* possesses memory gave negative results, but as these were undertaken near the end of the writer's stay at Loggerhead Key, they are not conclusive, and must be continued later.

Prof. Herbert S. Jennings pursued studies of the behavior of various actinians, corals, and echinoderms, this work being a continuation of his well-known studies upon the behavior of unicellular organisms, wherein he has demonstrated that the method of trial and error applies to behavior throughout the animal kingdom. His work upon these metazoans was devoted to the important problem of the modifiability of behavior, an understanding of which is essential be-

fore we can hope to comprehend the problems of even the simplest animal reactions. Professor Jennings presents the following statement of his results:

Preliminary Report by H. S. Jennings.

While at the Carnegie Laboratory at the Tortugas, in June, 1905, the writer devoted himself to a study of the behavior and reactions of the sea anemones The opportunities for this work were excellent, as many kinds of sea anemones are found in this region, many of them large and very favorable for such work. Attention was directed particularly to the problem of the modifiability of behavior in these very low organisms, and most interesting results were obtained along this line. A paper embodying the results of this work is to appear in the November number of the Journal of Experimental Zoology

Prof. Henry F. Perkins pursued studies of the Medusæ with a view not only to discover new or interesting species, but also to obtain data upon the non-radial sequence in the development of the marginal otocysts of hydromedusæ. His discovery of non-radiate sequence in these organs is well known from his work upon *Gonionemus,* and while at Tortugas he obtained abundant material for extending this investigation to the Leptomedusæ. He presents the following summary of his work at Tortugas:

Preliminary Report of Henry F. Perkins.

A systematic daily study was made of Medusæ taken in the tow net, and thirty-four species were found. Comparison was made between the Medusæ of Tortugas and those of northern stations, and studies were carried out upon anatomical and other causes of habitat determination.

Cassiopea xamachana and *C. frondosa,* which were discovered in the salt-water moat of Fort Jefferson, have never before been found together.

A study of the habits and life history of *Cassiopea xamachana* was carried out in order to draw a comparison between its behavior at Tortugas, and at other localities, from which the species has been obtained. A peculiar reproduction by budding was observed in its scyphistoma larvæ.

A new hydromedusa, *Cladonema mayeri,* was also found in great abundance in the moat of Fort Jefferson, and its hydroid stage was found in the same locality upon algæ. The Medusa displays 6 oral and 9 marginal tentacles; 6 radial canals arise from the manubrium, but three of these immediately bifurcate, so that 9 canals reach the margin of the bell. The processes of production of eggs in the Medusa and of Medusa buds in the hydroid were followed in detail and the habits of the animal were noted.

A new species of campanularian hydroid, *Platypyxis digitalis,* was also found in the moat. It is very minute, and arises singly from a stolon clinging to alga. The productive calicle, with developing Medusa buds, was discovered.

Aglaura ciliata sp. nov. is a Medusa having small tentacles and strongly ciliated proboscis. It was taken on the surface in July.

Prof. Jacob Reighard carried out a series of ingenious and pains-taking experiments upon the possible ability of predaceous fishes to distinguish warning color, if such exists, in the brilliantly colored fishes of the coral reefs. The very remarkable display of beautiful color among the smaller reef-fishes has commonly been supposed to serve as a warning to possible enemies, and to be associated with distastefulness or poisonous qualities. This hypothesis of warning coloration has become one of the fundamental corollaries of the theory of natural selection. Yet it rests upon but little experimental evidence, and practically none in so far as fishes are concerned.

Professor Reighard's experiments have thrown much light upon this crucial problem, and no more conclusive experiments have ever been made upon the subject of warning coloration. It is to be hoped that his researches in this direction may be largely extended. His preliminary report is presented herewith:

Preliminary Report of Jacob Reighard upon Warning Coloration in Reef-Fishes.

I studied the habits and adaptations of the coral-reef fishes with a view to a possible explanation of the remarkable diversity of form and color which they exhibit. Most of my time was spent in a preliminary investigation of warning color.

The gray snapper (*Neomaenis griseus*), the commonest predaceous fish of the region, was experimented on in mass and without removing the fish from its natural environment. The purpose of the experiments was to determine whether warning color is possible in the case of these fish, and whether any of the bright-colored fish of the region actually are warningly colored for the gray snapper.

The commonest food of the gray snapper is a very abundant, small silvery fish, *Atherina laticeps*. By imparting to *Atherina* a variety of brilliant artificial colors it was learned that none of these colors *in themselves* acted as warning colors for the gray snapper. In the same manner it was shown that the gray snapper is not color-blind, but distinguishes colors, or at least, certain colors. When the colored Atherinas were given a variety of odors or tastes, most unpleasant to man but not normal to the environment of the fishes (40 per cent formaldehyde, pure clove oil, carbon disulphide, formic acid, quinine, red pepper, etc.), they were still eaten by the hungry gray snappers, and without appreciable hesitation. But when there was imparted to the colored Atherinas a disagreeable quality normal to their environment, there was soon established for the gray snapper a transient association between the unusual color or unusual form of the Atherinas and the unpleasant quality of taste or smell. Thus blue Atherinas to which were attached portions of Medusæ (*Cassiopea*) containing nematocysts were at first taken readily, but after two or three hours they were refused. Pieces of the arms of *Cassiopea* that were shaped and colored so as to closely resemble Atherina, were at first taken, but after a very few minutes were refused. Thus an artificial warning, whether of color or form, was established, and by means of it the modi-

fied Atherinas were temporarily protected from the gray snapper. Most of these experiments need to be repeated, and all of them need to be extended. They indicate warning color as psychologically possible, but they by no means prove that it exists.

To test the latter question as many of the reef-fish as could be obtained were thrown living to the snappers, and all the species without exception were taken. There was no hesitation except in the case of some specimens of *Chylomycterus*. The following species were available, most of them in numerous individuals: *Abudefduf marginatus, Apogon sellicauda, Chylomycterus schoepfi, Haemulon flavolineatum, Iridio bivittatus, Neomaenis griseus* juv., *Pomacentrus leucostictus* (in all its color variations), *Thalassoma bifasciatum, Thalassoma nitidum.* These species, although few in number, show a considerable variety of brilliant colors and numerous color patterns all wholly familiar to the gray snapper. Feeding experiments of this sort should be extended to include all the fishes of the reefs. The fish must be *liberated* among the snappers. If offered as bait on a hook attached to a line they are commonly refused, and the impression may thus arise that the fish are warningly colored

The conditions at the Tortugas are peculiarly favorable for the work of the sort here outlined. The water is very clear and nearly always quiet, the reefs lie at the door of the laboratory; the fish occur in great variety and abundance; there is no commercial fishing. Here, if anywhere, should one be able to study many biological problems by working at fish while they are in their natural environment and under no restraint, and by checking the results thus obtained in a suitably equipped laboratory immediately at hand.

Alfred G. Mayer studied the rhythmical pulsation of Scyphomedusæ and the nature of the response of the Atlantic palolo, which swarms each year within three days of the last quarter of the July moon. Drawings were also made of all new or interesting Medusæ previous to the arrival of Prof. Henry F. Perkins, who then took up the study of the Medusæ.

Preliminary Report of Alfred G. Mayer upon the Rhythmical Pulsation of Scyphomedusae (Tortugas Laboratory, April-August, 1905).

If we cut off the marginal sense-organs of the scyphomedusa *Cassiopea*, the disk* becomes paralyzed and does not pulsate in sea-water. The disk will pulsate in sea-water, however, if we make a series of concentric, broken-ring-like cuts through the muscular tissue of the sub-umbrella. Then upon momentarily stimulating the disk, in any manner, it suddenly springs into rapid, rhythmical pulsation so regular and sustained as to recall the movement of clock-work.

It is not necessary that the cuts through the sub-umbrella tissue of the disk be concentric circles, for any shape will pulsate which allows contrac-

*In this report the term "disk" will be used to designate Medusæ from which the marginal sense-organs have been excised, while the term "Medusa" will designate the normal perfect animal.

tion waves to proceed *unhindered* in the direction of the trend of the circular muscle fibers, and at the same time opposes a *partial* barrier to their transmission across the muscle fibers. The pulsation is effected through the muscle fibers rather than through the nerve fibrillæ of the sub-umbrella. It will not start unless the disk be momentarily stimulated, as by a mechanical shock or a touch of a crystal of K_2SO_4, but once started it continues indefinitely without further external stimulation.

The waves of pulsation all arise from a definite point, and the labyrinth of muscular tissue around this center must form a closed circuit. This labyrinth may be simplified after the rhythmic movement has started, by cutting parts of it away, and thus forms may be *derived* which could not have been set into continuous pulsation in the first instance. Any cut which breaks the circuit, however, instantly stops the pulsation, and sustained movement can not be re-started.

The *rate* of pulsation of these disks is fully twice as fast as that of the normal perfect Medusa. This rate remains constant in the pulsating disk, and when pulsation ceases all movement stops *instantly*, never gradually. The rate is controlled by the center of pulsation, and does not depend upon the shape or complexity of the labyrinth of tissue formed by the cuts. In this respect it differs from the control of the marginal sense-organs for small pieces of tissue with a marginal sense-organ attached pulsate slower than large ones The tissue of the disks pulsates at the maximum rate at which it is capable of transmitting successive waves of contraction.

Disks with radial cuts or cuts *crossing* the trend of the circular muscles can not be made to pulsate continuously.

The disks of *Aurelia* and *Dactylometra*, if cut as described above, will pulsate as does the disk of *Cassiopea*.

These experiments show that rhythmical pulsation may be initiated and maintained independently of the nervous system, and that it may be myogenic in character. Pulsation must arise from a definite center, but this center may be established at any point in the muscular layer of the sub-umbrella. Once established it remains at a fixed point, while the disk continues to pulsate. Sustained pulsation occurs only in tissue forming a closed circuit,* and may therefore depend upon an electrical transmission of energy. These experiments appear to be the first in which paralyzed tissue has been restored to sustained pulsation without subjecting it to the influence of unnatural or injurious solutions.

If normal perfect Medusæ be lifted out of the water and then thrown back, the *rate* and amplitude of their pulsation suddenly increases. Pulsating disks react in a similar manner, but in their case only the *amplitude* increases, the *rate* remaining practically constant. The presence of marginal sense-organs is therefore not necessary either for ordinary pulsations or for the display of "excitement."

Removal of the mouth-arms and mouth-arm plate of *Cassiopea* prevents regeneration of marginal sense-organs and lappets if these also be removed. If, however, the stomach cavity be left intact, the margin of the disk will regenerate its sense organs and lappets. This contradicts Zeleny's law that

*Very elongate and involved spirals may occasionally be set into sustained pulsation, but this is probably due to electrical leakage back to the center through the gelatinous substance of the disk.

"the animal with the greater number of removed parts regenerates each part more rapidly than the one with the lesser number of removed parts."

The disk of *Cassiopea* is stimulated into temporary pulsation by all salts of potassium, sodium, lithium, barium, and by iodine, weak acids, ammonia, and glycerin. Loeb's contention that pulsation can not take place in a solution of a nonconductor, such as glycerin, is not supported.

Magnesium, calcium, and strontium salts do not stimulate the disk, and produce no contractions.

The sodium chloride of the sea-water is the chief stimulant to pulsation in *Cassiopea,* while magnesium is the chief restrainer of pulsation and counteracts the influence of the sodium chloride Thus, *Cassiopea* will pulsate in a pure 5/8 normal NaCl solution for half an hour, but comes to rest in less than 2 minutes in a solution containing the amounts and proportions of NaCl and magnesium found in sea-water.

The calcium of the sea-water assists the NaCl to resist the retarding effects of magnesium Thus, *Cassiopea* will pulsate longer than an hour in a solution containing the amounts and proportions of NaCl, magnesium, and calcium found in sea-water; but ceases to pulsate in less than 2 minutes in a solution containing only the NaCl and magnesium.

Unlike calcium, potassium does *not* assist the NaCl to overcome the stupefying influence of the magnesium Thus, *Cassiopea* ceases to pulsate almost as quickly in a solution containing the NaCl, magnesium, and potassium of sea-water, as it does in a solution containing only the NaCl and magnesium.

The potassium of the sea-water serves to stimulate pulsation in connection with both calcium and NaCl. Thus, *Cassiopea* pulsates only temporarily and with about a normal rate in $NaCl+K_2SO_4$ or $NaCl+CaSO_4$, whereas it pulsates continuously and at fully twice its normal rate in $NaCl+K_2SO_4+CaSO_4$.

We see then that the NaCl, K, and Ca of the sea-water unite in stimulating pulsation and resisting the stupefying effect of the Mg. All together they produce an indifferent fluid which neither stimulates nor stupefies the disk of *Cassiopea.* The explanation is quite different from that of Loeb in his account of the pulsation of *Gonionemus.*

The sea-water is an indifferent fluid for the disk of *Cassiopea,* and it does not pulsate when its marginal sense-organs are removed, simply because the sea-water does not stimulate it. If stimulated in sea-water, in any manner, it pulsates readily. This is also true of *Gonionemus,* and Loeb's statement that the K and Ca of sea-water inhibit pulsation is not supported; for the center of *Gonionemus* will pulsate actively in sea-water whenever it is touched by a solution of *potassium* salt, or otherwise stimulated. It does not pulsate ordinarily in sea-water simply because the sea-water does not stimulate it.

On the other hand, the disks of *Aurelia* and *Dactylometra* pulsate in sea-water as soon as they recover from the shock of the operation resulting in the loss of their marginal sense-organs. Unlike *Cassiopea* and *Gonionemus,* both *Aurelia* and *Dactylometra* are weakly stimulated into pulsation by magnesium, and thus the sea-water *as a whole* weakly stimulates them, producing irregular but sustained pulsations.

The central disk of *Cassiopea* will pulsate longer than an hour in a solution resembling sea-water but *lacking* calcium, whereas the normal perfect

Medusa, or parts of the margin containing sense-organs, cease to pulsate in this solution in less than 6 minutes. The marginal sense-organs can not send forth stimuli producing contractions unless they be constantly supplied with calcium from the sea-water, whereas the disk itself is relatively independent of the calcium of the sea-water.

On the other hand, both the disk and the perfect Medusa will pulsate in sea-water saturated with $CaSO_4$. The pulsation of the disk is therefore not dependent upon a definite and precise proportion between the calcium and the Na and K of sea-water, as was claimed by Loeb to be the case in *Gonionemus*.

CO_2 dissolved in sea-water quickly paralyzes the disk, but has little effect upon the marginal sense-organs.

Cassiopea will pulsate fully half an hour in a pure 5/8 normal NaCl solution, but is almost instantly stopped in an isotonic solution of Na_2CO_3. Indeed, it pulsates longer in LiCl than in Na_2CO_3. Evidently the salts themselves as well as their ions have much to do with pulsation. This is opposed to Loeb's view.

If the otolithic masses of the marginal sense-organs contain combinations of Na, Ca, K, and Mg (such as $K_2Ca_4Mg(SO_4)_6$, $K_2Ca(SO_4)_2$, $K_2Ca_2Mg(SO_4)_4$, or $K_2Mg(SO_4)_2$), and if potassium be constantly dissociating the disk would be set into contraction by the free K_2SO_4. Then if this contraction caused the K_2SO_4 to again combine with the Ca or Mg, or to dissolve out into the sea-water or into the gastro-vascular space, the stimulus would cease and no other contraction would follow until more potassium salt was set free. Preliminary experiments indicate that some such reaction may possibly take place in the otolithic masses, but I am not yet prepared to assert it as a fact. It would readily account for the slow, fairly regular control of the sense-organs over pulsation.

The paper of which the above is a partial summary will appear as a bulletin of the Carnegie Institution.

Report upon the Nature of the Stimulus which Produces the Swarming of the Atlantic Palolo, by Alfred G. Mayer.

For five years the Atlantic palolo worm, *Eunice fucata,* has been seen to swarm in great numbers upon the surface of the sea at Tortugas, and to cast out its genital products, early in the morning of a day within three days of the time of the last quarter of the July moon. This year (1905) the worm swarmed in vast numbers on July 22, and smaller swarms occurred on July 21 and 23. The last quarter of the moon fell on July 24. What was more remarkable, however, was the fact that a small swarm also occurred on July 9, 1905, and this was the day of the first quarter of the July moon. The worm was seen upon no other morning, although the ocean was watched constantly from April 22 to July 26. Evidently, then, the worm tends to respond to the first as well as to the last quarter of the moon.

As is well known, the complete worms live in cavities in the corroded and dead coral rock, or coquina, and on the morning of the swarm the posterior extremity is cast off and swims upon the surface, traveling with the posterior end moving forward and twisting in the direction of the hands of the clock, when viewed from the broken anterior end of the swimming part of the worm.

A number of large corroded coral rocks were placed in live-cars, which floated upon the ocean, while others were placed in a box fastened to the ground, and in which the tide rose and fell. One of the floating live-cars was open to the light both day and night, and the worms in the rocks in this car swarmed normally on the morning of July 22. As these rocks had been in the car for a month floating upon the sea, and not subject to rise and fall of tide, it is evident that the worms do not respond to a condition of the tide, but must respond either to the light or the position of the moon, or to some emanation from the moon, or to all three.

Another large floating live-car was covered every night with a wooden cover for a month previous to the swarm, so as to exclude the moonlight. Unfortunately it was darkened also during the day for about a week of this time, during the enforced absence of the writer. None of the worms swarmed in this car, but on cracking open the rocks it was found that although many of the worms were full grown, they had not become sexually mature. Sexually immature worms never swarm; hence the experiment is inconclusive and must be tried again, taking care to allow sunlight to fall upon the rocks each day.

The worms in a darkened box in which the tide rose and fell did not swarm Evidently light is necessary for the worms to become sexually mature, and this seems somewhat remarkable, as they live hidden away in the dark crevices of the rocks. It is probable that the worms respond to the position of the moon, for the Japanese palolo, according to the Izuka, swarms within three days after the day of the new and the full moon, and thus evidently does not respond to a certain intensity of moonlight. Moreover, the Atlantic and Pacific palolo worms swarm either in clear or in cloudy weather.

The laboratory was closed for the season on July 26, and the *Physalia* was brought up to Miami, Florida, and laid up in the fresh water of the Miami River, where she will be secure from the most severe storm. I take pleasure in reporting that the yacht and laboratory, and other property of the Carnegie Institution intrusted to my care, are in good order.

It is with great pleasure that we acknowledge our debt of gratitude to Captain George P. Colvocoresses, U. S. N., and Captain William H. Buhler, U. S. N., successively commandants of the Key West Naval Station, for their many acts of kindness and cordiality displayed toward all connected with the laboratory. Without this generous aid the laboratory could not have been efficiently maintained.

BOTANY.

EXPERIMENTS IN PLANT DEVELOPMENT.

Burbank, Luther, Santa Rosa, California. Grant No. 221. $10,000.

The experiments under way are the most extensive ever carried out, but from their very nature valuable results, either practical or scientific, can not be obtained at once. The pursuit of long periods of intensely careful and most accurate observations on a broad and comprehensive scale is the only course whereby results which will stand the test of time may be obtained. The laboratory and small field experiments of the past have never included enough species under study at the same time, and it has been impossible to draw general conclusions safely, as the different tribes and species of plants have each a slightly different story to relate. Very strong points are brought out by studying the results of these vast experiments, and much valuable material for thought will undoubtedly be found in the scientific account of the experiments.

Some of the experiments which have been carried on for the last 15 to 38 years are just coming to fruition. A partial list of the plants upon which work is now progressing includes 300,000 new hybrid plums, the work of the past 25 years in crossing about every known species, and about 10,000 seedlings of this year's growth; 10,000 new apples; many thousand peach and peach-nectarine crosses; 8,000 new seedlings of pineapple quince; 400 new cherry seedlings; 1,000 new grapevines; 8,000 new hybrid chestnuts, crosses of American, Japanese, Chinese, and Italian species; 800 new and distinct hybrid walnuts, crosses of American black, Sieboldi, English, Manschurica, butternut, and others; many thousand apricots and plumcots; 5,000 select, improved, thornless "Goumi" (*Eleagnus*) bushes; very numerous other fruits in less numbers, and 10,000 new, rare, hybrid seedling potatoes.

For the past eight years Opuntias and other cacti have been secured from all parts of the world. Selections have been made and crossed and thousands of hybrid seedlings raised, some tender or hardy or gigantic or dwarf; some bearing gigantic fruits in profusion and other small ones of exquisite flavor. Some large groups have been developed which produce enormous quantities of nutritious food for all kinds of stock and poultry. This work promises well for science and economics. Perhaps the next in importance are the experiments on grasses and forage plants. Some new ones of great value are being produced and some of rare scientific value in the study of heredity and variation.

DESERT BOTANICAL LABORATORY, TUCSON, ARIZONA.*

Dr. W. A. Cannon, the resident investigator, carried out an inquiry in the comparative anatomy of plants growing in dry and in irrigated soil, and among other results found that the irrigated individuals do not carry the development of the conducting system as far as those growing under natural conditions. The greater capacity of the conducting organs of the latter enables them to make use of the rainfall during the brief period in which it is received. Observations have been begun on the transpiration of salt-loving plants.

Prof. F. E. Lloyd, of Columbia University, under a grant from the Carnegie Institution of Washington, was in residence at the laboratory from June 11 to July 24, 1905. He continued his studies on the stomatal action of *Fouquieria splendens*, which were begun in 1904. He perfected a means of preserving the stomata in the condition assumed by them in nature, and extended and verified by numerous experiments the conclusions reached in his earlier studies. His investigations lead to a new interpretation of the essential nature of the guard cells of the stomata. Further details concerning his work may be found in his report.

Dr. V. M. Spalding, under a grant from the Carnegie Institution, occupied a table at the laboratory from October, 1904, until April, 1905, continuing his investigations on the biological relations of desert shrubs. He showed that there is a very intimate relation between the rate of transpiration and the character of the water supply and established the necessity of determining the water relations when the effect of any stimulus (as sunlight) on the rate of transpiration is in question. He also investigated the absorption of water by the leaves of various desert plants. In addition to the investigations mentioned above, he began a botanical survey of the immediate locality, including the laboratory tract, and laid the foundations for a thorough study of this subject.

Mrs. Effie Southworth Spalding continued her observations on the adjustment of the giant cactus to various external factors. In the preceding year an investigation was made on the changes which this cactus undergoes with a variation in the amount of water stored up in its tissues. During the present year the influence of temperature variations as well were observed and measured. A means of measuring changes in height, with special reference to growth, was

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*Grant No. 220. (For first report, see Year Book No. 2, p. xxvi; for second report, see Year Book No. 3, p. 98–100.)

devised and perfected, and the sizes of several cacti were taken and carefully recorded, so that we shall have exact data regarding the growth of these interesting desert forms.

Dr. D. T. MacDougal has continued his observations upon soil temperatures, and now has a series of instruments in action taking records at the laboratory, at the New York Botanical Garden, and at the Tropical Laboratory at Cinchona, Jamaica.

Dr. MacDougal also made an examination of the Delta of the Rio Colorado and adjacent deserts, the results of which are embodied in a geographical paper now in press.

Allen, Charles E., University of Wisconsin, Madison, Wisconsin. Grant No. 159. *Study of homologies of the gametophyte and sporophyte, etc., at Bonn University, under Prof. Strasburger.* $1,000.

Abstract of Report.—The work was carried on in the laboratory of Professor Strasburger at the University of Bonn, Germany. Four weeks were also spent in the collection and preparation of material at the zoological station, Naples. The more important results of a first study were embodied in a paper entitled "Das Verhalten der Kernsubstanzen während der Synapsis in den Pollenmutterzellen von Lilium canadense," published in the "Jahrbücher für wissenschaftliche Botanik," Band 42, Heft 1. A second study of the nuclear and cell divisions in the germination of the oöspore of Coleochaete resulted in the publication of "Die Keimung der Zygote bei Coleochaete," in the "Berichte der Deutschen Botanischen Gesellschaft," Band 23, Heft 7.

The material of the Rhodophyceæ collected at Naples and another collection of Spirogyra made during the summer will be used as the basis for further study.

Dean, Arthur L., Yale University, New Haven, Connecticut. Grant No. 161. *Investigation of the proteolytic enzymes of plants.* $1,000.

Abstract of Report.—In the investigation of the proteolytic enzymes of plants it was shown that these enzymes are present in a number of plant tissues. The process of proteolysis in *Phaseolus vulgaris* was made the subject of special study. It was demonstrated that the germination of the seeds of this plant is accompanied by a cleavage of the proteids present, though no tryptic enzyme occurs. An active ereptic enzyme was found and preparations of it made and studied. This enzyme was also found in the seedlings and in all tissues of the adult plants. A quantitative comparison of the ereptic activity of the various tissues showed that the roots contained the most enzyme per unit of nitrogen.

Livingston, Burton E., Bureau of Soils, U. S. Department of Agriculture. Grant No. 156. *Investigation of the relations of desert plants to soil moisture and to evaporation.* (For first report see Year Book No. 3, p. 100.) $400.

Dr. Livingston reports that the work is completed and gives the following summary of results:

(1) The deeper soil layers of the laboratory hill contain at the end of the spring dry season, and thus probably at all times, a water content adequate to the needs of those desert plants which are active throughout the months of drought.

(2) This conservation of moisture in the soil is largely due to the high rate of evaporation and the consequent formation of a dust mulch. It is partly due to the presence of rock fragments and of a hard-pan formation called "caliche."

(3) Desert forms show an adaptation to existence in dry soil, being able to exist in soils somewhat drier than those needed by plants of the humid regions, but this adaptation is comparatively slight and can not be considered of prime importance.

(4) The downward penetration of precipitation water is slow through the adobe soil itself, but comparatively rapid on the whole, on account of the presence of numerous oblique rock surfaces along which the flow is not markedly impeded.

(5) By the middle of the summer rainy season all of the soil excepting the first few centimeters is sufficiently moist to allow germination and growth of most plants. The surface itself is often wet for periods of several days during the season of summer rains.

(6) Seeds of *Fouquieria splendens* and of *Cereus giganteus* fail to show any special adaptation to germination in soils drier than those needed by the seeds of such mesophytes as *Triticum* and *Phaseolus*.

(7) Immediately following germination the seedlings of desert plants exhibit a slow aerial growth, but an exceedingly rapid downward elongation of the primary roots, so that these soon attain to depths where moisture is always present in adequate amount for growth.

(8) The high moisture-retaining power possessed by the soil of the laboratory hill holds near the surface much of the water received from a single shower and offers excellent opportunity for the rapid absorption of this by such shallow-rooting forms as the cacti.

(9) The saps of *Cereus*, *Echinocactus*, and *Opuntia* exhibit osmotic pressures no higher than those commonly found in plants of the humid regions.

(10) The effect of air currents in increasing evaporation and trans piration rates is so great that reliable measurements of transpiration can not be made in closed chambers.

(11) By a new method, involving a newly devised evaporimeter, a physiological regulation of the rate of transpiration was unquestionably shown to exist in the forms studied.

(12) The regulation of transpiration seems to be controlled by air temperature, the checking of water loss beginning to be effective between 79° and 90° F., and the check being removed between 75° and 80° F.

(13) The ratio of transpiration rate per unit leaf surface to evaporation rate per unit water surface is termed relative transpiration. Relative transpiration is reduced by the regulatory response from unity in the high periods to from one-twelfth to one-sixth in the low periods.

Lloyd, Francis E., Columbia University, New York, N. Y. Grant No. 285. *Study of correlation between stomatal action and transpiration in types of desert plants.* $500.

Abstract of Report.—The results of the previous summer's work upon *Fouquieria splendens* were reëxamined and verified. The work this summer (1905) was based more particularly upon *Verbena ciliata*. All the investigations have been carried on at the Desert Botanical Laboratory at Tucson.

The conclusions reached are as follows:

The direct observation of stomata at all hours of the day and night indicates that the normal changes which occur in the form of the stomata are slow. Rapid changes do not appear to occur except during rapid wilting. The quantitative study of this phenomenon and the observation of stomata in controls have resulted in the conclusion that the closure not only does not occur in anticipation of "visible wilting" (of certain authors), but, quite contrariwise, lags behind. The view that the stomata are devices with large efficiency to control transpiration is thus called into question. Although the rates of transpiration during the day and night have not yet been fully worked out, it is probable that the curve expressing them will be similar to that constructed for *Fouquieria splendens*. This probability is increased by the fact that the maximum opening of the stomata is between 8 and 9 a. m. (in the summer months), several hours before the maximum rate of total transpiration, according to the usual expectation, is reached.

The stomata are most nearly shut early in the morning, before dawn. They are normally only partially closed at night. After sunrise they slowly open till 8 or 9 a. m., after which they slowly close, but only so much as to contract the opening to perhaps one-third its transverse diameter.

Contrary to the general belief, the plastids of the guard cells are not provided with chlorophyll, and this appears to be true of many other plants. There is conclusive evidence also that the physiology of the guard cell is quite different from that of the chlorenchyma cells of the leaf. In the latter the accumulation of starch occurs during daylight, commencing at sunrise and increasing during the day till nightfall. Conversely, during the night the starch thus accumulated slowly disappears, and is absent from the plastids by daybreak. In the guard cells, however, the starch found at nightfall does not disappear from the plastids, so that at daybreak it is abundant. During the hours between daybreak and 9 a. m., or somewhat earlier, the starch content gradually disappears, until little or none i
At the same time an oil, not present (or if so in inappre
tities) at dawn, accumulates until large drops of it are pr
one in each cell. They are easily mistaken at first fo
their resemblance to these bodies is merely superficial
slowly disappears again until, at the close of day, it is
if present is in inappreciable quantities. During this san
namely, from 9 a. m. till sunset, the starch content is increasing, but experimental inquiry indicates that this accumulation of starch is not dependent, wholly at least, upon the presence of light, nor directly to the presence of carbon dioxide. These conclusions point very directly to the necessity of turning attention to the internal physiology of the guard cells.

The methods employed were those previously devised during the summer of 1904, and were described before the Botanical Society of America at the Philadelphia meeting, 1904–1905.

Olive, Edgar W., University of Wisconsin, Madison, Wisconsin. Grant No. 271. *Researches on the life histories and cytology of certain lower plants.* (For previous reports see Year Book No. 2, p. xxvii, and Year Book No. 3, p. 101.) $1,000.

Abstract of Report.—Two papers, representing the writer's earlier work as an associate of the Carnegie Institution of Washington, have been published during the year—one on the structure of the blue-green algæ and one on *Monascus*. Two other articles are in press—

one, "Notes on the occurrence of *Oscillatoria prolifica* in the ice of Pine Lake, Waukesha County, Wisconsin," and another on "Cytological studies on the Entomophthoreæ: I and II. Cell and nuclear division and development of *Empusa.*"

The presence of great quantities of *Oscillatoria prolifica* gave to the ice a reddish color, while the release of the alga by the melting of the ice in the spring was accompanied by disagreeable odors from the decay of the plant. Nuclear and cell division were described for two species of *Empusa*, while six species furnished material for a study of the general morphology of the group. The nuclear division was found to resemble closely that of certain protozoa, in that intranuclear centrosomes appear to control the process.

Spalding, Volney M., Tucson, Arizona. Grant No. 287. *Investigation of absorption and transpiration of water by the creosote bush and other desert shrubs.* (For first report see Year Book No. 3, p. 102.) $600.

Abstract of Report.—As part of the general study of the water relations of desert shrubs, an investigation of leaf absorption has been made. It has been found that certain species absorb, in appreciable quantities, water presented to their leaves and internodes, while others do not. The quantity of water absorbed has in some instances amounted to 100 per cent of the weight of the entire seedling above ground. The capacity for leaf absorption is correlated with other peculiarities of habit and structure which have been made the basis of a classification of the plants of the region in which the Desert Botanical Laboratory is situated into biological groups, the validity of which will be further tested by work now in progress.

Swingle, Walter T., Department of Agriculture, Washington, D. C. Grant No. 235. *Investigation of electromagnetic and electrostatic effects on lines of force found in living plant cells.* $1,500.

Abstract of Report.—Mr. Swingle reports that active work on this investigation was postponed until the end of the fiscal year, June 30. Since then, however, much progress has been made with the able assistance of Dr. L. J. Briggs, Prof. A. G. McCall, and Mr. W. Marquette. The material which Mr. Swingle procured on the Pacific Coast during the winter has been studied and promises to yield important results.

After working in Washington for a short while it became evident that suitable transparent objects could not be obtained here. Accordingly permission was obtained to make use of the facilities of the biological laboratory of the Bureau of Fisheries at Beaufort, North

Carolina, at which place eggs of sea-urchins and tunicates, admirably suited for the purpose, were found. The conditions have probably never been so favorable for a test of the effects of electrostatic and electromagnetic fields on the lines observed in the living cell, as the eggs under observation were large and transparent, and some of the radiations surrounding the center were seen very clearly in the living cell in its natural environment. One of the most satisfactory results was that it was found possible to ship to Washington living marine animals having eggs in first-class condition on arrival. Some eggs studied reached the 128-cell stage in three hours or less, or made the equivalent of 127 divisions in this short time. Preparatory to each division the whole cell was filled with radiations of exceptional clearness.

Laboratory research in Washington has been in the nature of a study of living and fixed cells in reference to the behavior of the lines of force during various periods of cell activity. The highest resolving powers of the microscope will be utilized. Mr. Swingle considers the evidence for the existence of a system of force in the living cell to be well-nigh conclusive.

In connection with the work it has become imperative to consult the principal papers on the cell, and there has therefore been begun and is well on the road to completion a comprehensive index on the literature of the cell. Various bibliographies have been photographed and are being arranged on cards, of which some 2,000 cards are now in use.

CHEMISTRY.

Abel, John J., Johns Hopkins University, Baltimore, Maryland. Grant No. 203. *Services of an assistant to continue the investigation of the chemical composition of the secretion of the supra-renal gland.* (For previous reports see Year Book No. 2, p. xxviii, and Year Book No. 3, p. 103.) $1,000.

Report.—Dr. Abel and Mr. R. de M. Taveau have continued their investigations on the composition and chemical constitution of epinephrin hydrate (adrenalin, suprarennin). The analytical results obtained speak rather for the correctness of the formula $C_{10}H_{13}NO_3$ $\frac{1}{2}H_2O$ than for that of $C_9H_{13}NO_3$. The researches of a number of other investigators have induced them to accept the latter formula as more closely representing the elementary composition of adrenalin. It is, however, pointed out by Messrs. Abel and Taveau in a paper now in press (Journal of Biological Chemistry, vol. 1, No. 1) that there are no means of purifying this substance except by methods open to criticism; that great difficulty is experienced in preparing stable and crystalline derivatives, and that great importance attaches to the preparation of specimens with a low nitrogen content, inasmuch as such are least likely to be contaminated with products of a high nitrogen content such as are known to exist in the supra-renal glands. The substance as prepared by Messrs. Abel and Taveau contains less nitrogen than was found by others, and inasmuch as their analytical findings agree with the empirical formula $C_{10}H_{13}NO_3\frac{1}{2}H_2O$, they have accepted this as truly representing the elementary composition of the substance. The half molecule of water ($\frac{1}{2}H_2O$) of this empirical formula is shown to be water of constitution, and the molecular weight of the substance must therefore be represented by at least $2(C_{10}H_{13}NO_3\frac{1}{2}H_2O)$. The molecular weight determinations which have appeared to support the mono-molecular formula have been critically examined by the writers and shown to lack the confirmatory value that has been attached to them.

When epinephrin hydrate is treated with boiling water in a current of pure hydrogen considerable quantities of ammonia and methylamine are liberated. When the base, $C_3H_4N_2O$, obtained from both epinephrin and its hydrate, is treated with a fixed alkali, it also yields ammonia and methylamine, and in addition methylhydrazine. The presence of the last-named substance among the degradation products of the base, $C_3H_4N_2O$, compels these investigators to believe that the two nitrogen atoms of this base are directly linked, the one to the

other, and that it has the chemical structure of an open chain or cyclic hydrazide. Such experiments as have been made by the writers induce them to believe that the base is a new and highly unstable cyclic hydrazide. The search for hydrazine or methylhydrazine among the decomposition products of epinephrin hydrate itself has not been rewarded thus far with success; but by means of appropriate methods skatol, protocatechuic aldehyde, and vanillin were obtained as decomposition products.

In consequence of the results obtained the writers are led to believe that epinephrin hydrate, $2(C_{10}H_{13}NO_3\frac{1}{2}H_2O)$, contains not only the protocatechuic complex, $C_6H_3.(OH)_2C$, but also the vanillic residue $C_6H_3.OH.(O.CH_3).C$. These aromatic residues are combined with a side chain containing two nitrogen atoms, one of which is present as a part of the group $.NH(CH_3)$, the other as a part of the group $:NH$. A further analysis of atomic groupings has not been attempted, especially in respect to the disposition of the hydroxyl groups which must be assumed to be present in the side chain of the molecule. The above arguments, together with others, have been duly set forth as objections against the validity of the constitutional formula $C_6H_3(OH)_2.CH.OH.CH_2.NH.CH_3$, now generally accepted as correctly representing the structure of the substance under discussion.

Some experiments were undertaken with the purpose of forming synthetically a number of physiologically active compounds which should contain one or more hydroxylated benzene residues associated with a nitrogenous complex containing two atoms of nitrogen.

Acree, Solomon F., Johns Hopkins University, Baltimore, Maryland. Grant No. 204. *Study of pinacone-pinacolin rearrangement and of urazoles.* $1,000.

Report.—In an article entitled "On the pinacone-pinacolin rearrangement (I)," which appeared in the American Chemical Journal, February, 1905, were described some new classes of pinacones and pinacolins and the rearrangements which these compounds undergo under certain conditions. In connection with this a new series of trialkyl glycolls, prepared by a method originated by the writer, was studied.

In an article now in course of preparation, "On the pinacone-pinacolin rearrangement (II): Reaction of sodium pinaconates," will be published the results of investigations on sodium pinaconates. These interesting compounds, in contrast to the corresponding pinacones or the bromagnesium salts, are very reactive toward air, water, acids, acid chlorides, carbon dioxide, aldehydes, ketones, esters, and

alkyl halides. When reacting with aldehydes and ketones, sodium benzpinaconate first dissociates into two products, according to the following equation:

$$(C_6H_5)_2=\underset{\displaystyle |}{\overset{\text{O—Na}}{C}}\text{———}\overset{\text{O—Na}}{\underset{\displaystyle |}{C}}=(C_6H_5)_2 \leftarrow (C_6H_5)_2=C=O+(C_6H_5)_2=\overset{\text{O—Na}}{C}\text{—Na}$$

The sodium compound thus formed, called benzophenone disodium, is very reactive toward all the above-named reagents, and by the use of this substance a number of new methods of synthesis have been made possible. For example, by the use of these sodium pinaconates and carbon dioxide we have a new and very advantageous method for the preparation of dialkyl glycollic acids, heretofore prepared only with difficulty.

The results of another line of investigation on the pinacones will appear under the title "On the pinacone-pinacolin rearrangement (III)." In this article will be described the general methods used in causing the rearrangement of a large number of pinacones, the constitution of the resulting pinacolins, and the mechanism of the reactions involved in these rearrangements. Directly connected with this will be described the work accomplished on the rearrangement of α, α dialkyl dihalogen ethanes, $R_2CH\ CHX_2$, into tolane derivatives $RC\equiv CR$, and of the corresponding trichlor compounds, $R_2CH\ CX_3$, into dialkyl ethylenes. As a further part of this large problem there will be described the work finished on the benzilic acid rearrangement.

In an article which has the title "On the constitution of phenylurazole (III)," is described the result of considerable work on the urazoles. These substances have especially important tautomeric properties, and it is extremely difficult to decide which one of the five possible formulæ should be assigned to phenylurazole. A large number of urazoles were synthesized in order to bring into the field of investigation a number of these compounds with characteristic properties; but by far the most important part of the work was the acquisition of further data, by the use of physical chemical methods, on the constitution of these compounds. The behavior of these urazoles is now much more easily understood, and it is hoped that not a great deal more work will be required to solve the problem satisfactorily

Bancroft, Wilder D., Cornell University, Ithaca, New York. Grant No. 236. *Systematic study of alloys.* (For previous reports see Year Book No. 2, p. xxix, and Year Book No. 3, p. 104.) $1,000.

Abstract of Report.—Papers on the tensile strength of copper-tin alloys and on the constitution of aluminum-zinc alloys have been

published. A paper on antimony-tin alloys is in press. In the zinc-tin alloys the solid phases are pure zinc and a solid solution containing 7 per cent of zinc. In the zinc-cadmium alloys two sets of solid solutions occur with 5 and 96 per cent zinc. Pure zinc and pure lead crystallize from zinc-lead melts. With zinc and bismuth the solid phases are pure zinc and a solid solution containing 3 per cent of zinc. Work is now being done on the possible allotropic forms of zinc. In the antimony-tin alloys there are four series of solid solutions and no compounds The third series, counting from the antimony end, is instable below 310°. The constitution of the copper-aluminum alloys has been determined over the range 0 to 65 per cent Cu. Experiments on the tensile strength of antimony-zinc alloys show that the maximum strength comes just where it should, at 50 per cent Al.

Baskerville, Charles, College of the City of New York, New York.
Grant No. 237. *Continuation of investigation of the rare earths.* (For first report see Year Book No. 3, p. 105.) $2,000.

Professor Baskerville submits the following abstracts of the several investigations carried out with the aid of grants from the Carnegie Institution of Washington.

ON THE ATOMIC WEIGHT OF CAROLINIUM.

CHARLES BASKERVILLE WITH FRITZ ZERBAN.

The investigation on the complexity of thorium was continued. It had been shown by previous experiments that thorium chloride, under certain conditions, may be fractioned into three substances of different volatility. The elements corresponding to these chlorides have been designated as berzelium, new-thorium, and carolinium. Baskerville and Davis had found the atomic weights of the new elements to be 212, 220, and 256, respectively. In a previous report by the junior author these figures were redetermined as being 212.3 for berzelium and 258 for carolinium.

In continuing the experiments about 100 grams of pure thorium oxide were separated into the three components by the method previously used. About 15 grams of carolinium oxide were obtained from the residues non-volatile at 760 ° C. A determination of the atomic weight of this material was started but not completed by the junior author. The method used for this determination was very similar to that described in the last report. The carolinium chloride was purified in the same way by evaporating with hydrofluoric and sulphuric acids repeatedly. The resulting sulphate was dis-

solved in cold water, precipitated with oxalic acid, and the oxalate ignited. The oxide thus obtained was of a slightly pinkish color. It was readily soluble in concentrated hydrochloric acid on boiling for about two hours. By evaporating a greater part of the liquid and cooling, very pretty crystals were obtained. They were then recrystallized from concentrated hydrochloric acid. Thus two portions of pure chloride were obtained, one of which had been recrystallized seven times and the other ten times. In order to remove the last possible remnant of impurities, the chlorides were dissolved in water, the solution filtered, and precipitated with oxalic acid. The well-washed oxalates were then ignited to the oxide, which was finally obtained as a fine powder nearly white in color. It dissolved readily in boiling concentrated hydrochloric acid.

The determination of the atomic weight of carolinium was carried out with this chloride solution. In the previous test two pairs of platinum crucibles had been used which were about the same weight respectively, so that crucible I could be used as a counterpoise of II, and crucible III as one of IV. Platinum is volatile to some extent at temperatures above 800°C., as shown by Hulett. In order to avoid errors resulting from this source, the two crucibles which were to counterpoise each other were heated at the same time in an electric resistance furnace built especially for this purpose. The shape of the furnace was similar to that placed on the market by Eimer & Amend, of New York. The dimensions of the interior of the furnace were 6¼ inches long, 3⅛ inches wide, and 3⅛ inches deep. By this arrangement the two crucibles could be placed in the furnace at the same time and heated to the same temperature. The furnace was covered with a sheet of platinum. On top of this plates of fireproof material were placed, which were again covered with brick made of similar material. The temperature of the furnace was determined with a le Chatelier pyrometer tube, which was carried into the interior through a hole driven through the covers. The platinum crucibles were supported in the furnace by means of platinum triangles in a way that prevented them from touching the bottom.

Although all care was taken to prevent errors by the arrangement described, it was found impossible to obtain a constant weight of the empty crucibles. The two crucibles were heated, at the same time, to 1200° C. for one hour and placed at once in a desiccator containing phosphorus pentoxide. The desiccator was exhausted, and after three-quarters of an hour the crucibles were weighed on a very accurate balance; but it was found that one crucible after each

hour had lost more platinum than the other counterpoised crucible. Although the heating was repeated for a great number of times, it was impossible to obtain a constant weight. Likewise, if the crucibles were transposed the result was not changed. For these reasons further heating was considered to be unnecessary. The difference in the loss of weight was of a constant value and could therefore be calculated for a certain period of heating.

After this experience it was tried whether constant weight could be obtained at a temperature of 400° C. We found that at this temperature constancy of the weight could readily be reached.

When the crucibles showed a constant weight at 400° C., chloride solutions of the two carolinium preparations were mixed, in platinum dishes, with a small excess of sulphuric acid. The liquids were then evaporated on a water-bath as far as possible and the resulting sulphates were dried in the platinum-bath devised by Baskerville and Davis, at about 350° C. They were then placed in the electric resistor-furnace and heated to constant weight at 400° C.

On account of the discrepancies observed when platinum was used, the determinations were not completed. Quartz crucibles were ordered, and the work will be repeated with them.

ACETYL-ACETONATES OF THE COMPONENTS OF THORIUM.

CHARLES BASKERVILLE WITH FRITZ ZERBAN.

Further experiments were made with the acetyl-acetonates of the three fractions, prepared in the same way as described in the last report. A determination of the atomic weight of carolinium, made with the acetyl-acetonate, had yielded the value 239.09.

As the melting-points of the acetyl-acetonates of berzelium, new thorium, and carolinium had been found to be the same, it seemed desirable to learn whether this fact really proved the identity of the three substances. Since in similar cases a simple determination of the melting-point of mixtures of two substances may be used for deciding this question, the three acetyl-acetonates were mixed in various proportions and the melting-points of these mixtures determined. It was found that the melting-points of these mixtures were exactly the same as observed for the pure compounds.

Nevertheless this fact can not decide the question of the identity or non-identity of the three substances, because in a very similar case Biltz made like observations. He found the melting-point of neodymium acetyl-acetonate as 144° to 146° C., that of praseodymium acetyl-acetonate as 146° C., and the melting-point of didymium acetyl-acetonate, which really represents a mixture of the former

two, as 147° C. (average), the different figures ranging from 142° to 152° C.

According to two analyses made with the acetyl-acetonates of carolinium and berzelium, the two substances seem to be different, in fact. The analyses yielded the following figures, respectively:

Cn. —0.8832 gram acetyl-acetonate gave 0.3770 gram oxide.

CnO_2.—42.69 per cent eq. wt. 59,7725, at. wt.^{IV} 239.09.

Bz. —0.2058 gram acetyl-acetonate gave 0.0852 gram oxide.

BzO_2.—41.4 per cent eq. wt. 56.29, at. wt^{IV} 225.16.

S. Jordan, in preparing a series of the organic salts of carolinium, examined the comparative behavior of the acetyl-acetonates of original thorium, carolinium, and berzelium. It was learned that carolinium acetyl-acetonate crystallizes readily from absolute alcohol and does not alcoholize, whereas the berzelium salt forms a gummy mass and crystallizes only with the utmost difficulty. The acetyl-acetonate of the original thorium appears a mixture of the other two. The gummy mass was allowed to settle, separated, the mother liquor evaporated; the impure crystals were redissolved in absolute alcohol, the process being repeated. The crystals after the sixth treatment melted at 172° C An atomic weight determination with the acetyl-acetonate gave the value 240.3, assuming carolinium tetravalent. This was confirmed by E. E. Randolph with still another preparation.

Although these facts and figures seem to prove beyond question the complexity of thorium, we are not yet ready to assert it as final. The absorption of gases by the oxides, which was first observed by Biltz, might have caused some discrepancies.

PREPARATION OF METALLIC THORIUM.

Charles Baskerville with Fritz Zerban and E. E. Randolph.

To settle definitely the elementary nature of the constituents separated from thorium, it became necessary to secure the metals themselves, that such physical constants as specific heat, specific gravity, etc., might be determined. On account of their similarity and value, preliminary investigations of methods were carried out with the ordinary thorium compounds.

The preparation of the metal, thorium, proved to be a very difficult problem, the solution of which required months of experimentation, as the literature provided much misinformation as to the purity of the compounds obtained by the methods described.

Apparently the purest metallic thorium which has been obtained up to this time was that made by Nilson. The previous experiments of Berzelius and Chydenius had yielded an impure metal. Nilson

started from the double chloride of thorium and potassium prepared by dissolving pure thorium hydroxide in pure hydrochloric acid, adding a calculated amount of potassium chloride, evaporating on water-bath to dryness, and then heating the resulting mass to redness in a current of dry hydrochloric acid gas. This double compound was readily and completely soluble in water; therefore Nilson concluded that it was K_2ThCl_6. This was reduced by means of metallic sodium in an iron cylinder which was heated, in a large Roessler gas furnace, to white heat. The double chloride was reduced to a gray metallic powder which took fire far below red heat. It was readily soluble in hydrochloric acid, slowly soluble in dilute nitric and sulphuric acids, and insoluble in a potassium hydroxide solution. The material contained oxygen. This Nilson attributed to occluded air between the particles within the cylinder, but Krüss later showed that the material used by Nilson was in fact an oxychloride of thorium combined with potassium chloride.

Our experiments on the reduction of thorium oxychloride by means of metallic sodium in a closed, specially constructed iron cylinder, from which the air was exhausted, gave us a gray powder with similar properties to that described by Nilson, but much contaminated with the oxide. It was impracticable to separate this oxide. We also made the following interesting observation: When our steel bomb, with walls of 2 cm. thickness, was heated by means of gas we invariably found thorium carbide as one of the contaminations of the metal as well. The gas evidently filtered through the steel.

Thorium readily forms a carbide when efforts are made to reduce the oxide by means of carbon in an electric furnace. This we have demonstrated in the preparation of considerable quantities of the carbide which are to be used in the investigations.

Efforts to electrolyze the tetrachloride with carbon and iron terminals in a copper furnace, according to the method of Muthmann, who in this manner prepared pyrophoric cerium, præseodidymium, neodidymium, and lanthanum, were fruitless. Thorium invariably forms the carbide when carbon is present and the metal is reduced at great heat.

An Heræus electric oven was substituted for the gas furnace. We obtained the metal with the oxide impurity as described above. It is in a fine state of subdivision, as the temperatures for such furnaces are limited to the fusing point of platinum, which is much below the melting-point of thorium. The melting-point of thorium has not as yet been definitely determined.

Two important points require consideration, namely, the affinity of thorium for oxygen and for nitrogen, and the high melting-point of thorium.

The illumino-thermit methods of Goldschmidt were tried with many variations. Thorium oxide, mixed with aluminum powder in calculated proportions and ignited with ignition mixture, is reduced, to be sure, but the reaction takes place at a comparatively low heat. The oxide is not completely reduced and the mass does not completely melt. Numerous efforts were then made to prepare alloys of thorium which, according to a general law, should melt at lower temperatures than pure thorium.

The use of zinc, lead, copper, and other metals or their oxides gave negative results. The reaction was so violent at times as to proceed with a pyrotechnical display and even dangerous explosions. Efforts were made to reduce the oxide and form an alloy by means of a large excess of aluminum in the powdered condition. An intimate mixture was made in crucibles lined with magnesium oxide and protected from the air by making a cement cover of magnesium oxide and chloride. These crucibles were subjected to the heat of a powerful boiler furnace for eight hours. While no satisfactory yield of metallic thorium or alloy of thorium and aluminum was had in this manner, an alloy of thorium, aluminum, and copper was obtained.

Another interesting point is to be noted here, namely, that the small amount of copper which occurs in ordinary aluminum is concentrated by the thorium. This may in part be removed by repeated digestion in ammonia, hydrogen dioxide, then electrolysis in oxalic solution.

Without enumerating many other efforts to obtain the metal, it will suffice to state that eventually we prepared the double potassium-thorium fluoride in an anhydrous condition and reduced it by means of finely divided aluminum which was free from copper. This was done in a crucible lined with magnesium oxide and protected from the air by a magnesia cover. Sufficiently high temperature was obtained by burying the crucible in a mass of kryptol, which was heated by the passage of a powerful electric current of 80 amperes and 220 volts. In order to heat the mixture evenly a copper wire was wound around the inner crucible several times in the form of a spiral. The heat could be readily controlled. In this manner a regulus of thorium and aluminum alloy was obtained containing a minimum amount of silicon. When the thorium and potassium fluorides were mixed in the proportion of 1 : 3 the regulus showed no crystalline structure under the microscope. When the proportion was 1 : 2 the mass was a nest of long crystals belonging to the hexagonal system. The aluminum

was removed by long and continued digestion in solutions of caustic potash. The silicon was removed by digestion in hydrofluoric acid. In this manner excellent needle crystals of metallic thorium were obtained which on analysis proved to be 99 per cent pure.

The metal is steel gray in color, does not change in the air, does not decompose in water, is not affected by cold or boiling water. It is attacked slowly by concentrated nitric and hydrochloric acids; is attacked readily by dilute hydrofluoric acid, and dissolves readily in dilute hydrochloric acid. At about 200° C. it burns in the air to the white oxide. In the finely divided condition it gives brilliant pyrotechnical display when sprinkled in the flame of the Bunsen burner. It burns brightly in a current of oxygen. When heated in ammonia gas it is converted into the hydride. There are apparently two stages for this reaction: first, it assumes a beautiful bluish-green iridescent color, and after treatment for five hours becomes a dark brown. The product is not decomposed by water or acids, but by fused caustic alkalies. These bodies will receive further attention.

The metal is converted into the nitride when heated in an atmosphere of dry nitrogen. At a low heat the metal combines readily with chlorine, bromine, iodine, and the vapors of sulphur and phosphorus. The specific gravity of the purest compound obtained was 10.95; the specific gravity of the regulus was 4, varying with the aluminum present. It is interesting to note that the metal possessed practically the same radioactivity as the ordinary pure thorium oxide. Having prepared 400 grams of this metal, it will be used for further experimentation looking toward the complexity of thorium. A portion of it has been utilized by Eberhard and Humphreys in obtaining an accurate spectrum for subsequent comparisons.

EXTRACTION OF INACTIVE THORIUM.

CHARLES BASKERVILLE WITH STROUD JORDAN.

The author and Zerban published (see report to the Carnegie Institution of Washington for 1904) the finding of a very small percentage of inactive thorium in a South American rock. Having secured 150 pounds of this material, we have investigated it with great care. We succeeded in obtaining from it about 1 pound of a black mineral, which appears to be new.* We have not determined this definitely, as the complete analysis has not been finished. By a very tedious process

*Through the courtesy of Dr. W. H. Nichols, president of the General Chemical Company, the heavy portion of this work was carried out in one of the factories at Laurel Hill.

we have extracted from it a small percentage of an oxide which responds to all the known chemical tests for thoria. However, it possesses no radioactivity whatever.

This observation is of unusual interest, for if it be thorium, then the advanced theories of Rutherford and Soddy as to the inherent radioactivity of thorium and its so-called disintegration are no longer tenable and must be rejected. If it be not thorium, then we have a new element, whose compounds resemble that element very closely and may prove to be one of the constituents the author has reported present in the usually accepted element of thorium. To determine this, atom weight determinations and the spectrum must be had. The former will be worked upon as soon as we shall have extracted sufficient of the material, as that already obtained has been turned over to Sir William Crookes, of London, and Dr. G. Eberhard, of the Royal Astrophysical Laboratory at Potsdam, who will make the spark and arc spectra, respectively.

ON THE COBALT-AMINES OF THE COMPONENTS OF THORIUM.

CHARLES BASKERVILLE WITH E. E. RANDOLPH.

Wolcott Gibbs found that luteo cobalt precipitated completely the four cerite earths—cerium, lanthanum, praseodymium, and neodymium—as neutral double sulphates. With this reagent he effected a separation of these four earths from erbium, yttrium, and ytterbium. He reported that luteo-cobalt-amine gave with solutions of thorium salts a "heavy fine yellow crystalline precipitate very difficultly soluble in cold water and practically insoluble in hot water." At his suggestion a study of the conduct of the various fractions with these cobalt-amines was undertaken. The outcome, as noted below, was most satisfactory and our thanks are due this distinguished pioneer in research in the rare-earth field.

Chlorides, nitrates, and sulphates of the fractions were prepared from the material obtained by Baskerville and Davis (J. Am. Ch. S., 26, 922). Neutral as well as slightly acid solutions were used. In all cases of comparison the conditions as to acidity, temperature, concentration, and the amount of solution and of reagent used were kept rigidly the same. Neither the chloride nor the nitrate of the original thorium or carolinium gave a precipitate with either of the cobalt salts used. There was no apparent difference between the action of the cobalt-amines and the neutral and weakly acid solutions of any of the salts.

Luteo and roseo cobalt-amines gave precipitates with the sulphate of the berzelium fraction, and formed characteristic crystalline double

salts with its chloride and nitrate. The only double salt obtained with the purpureo cobalt-amine was with the berzelium nitrate. The crystals were of a beautiful deep violet or purplish-red color.

The luteo cobalt gave a fine yellow microscopic crystalline precipitate with carolinium sulphate which was very insoluble. The roseo salt was obtained in well-defined crystals of a light-reddish tint.

The purpureo salt gave no precipitate with berzelium sulphate, as noted.

The original thorium-sulphate solution on treatment with luteo cobalt-amine gave at first the yellow crystals characteristic of the carolinium sulphate and then a second lot of large red crystals similar in appearance to the double salt obtained with berzelium chloride. While a separation could be made by taking advantage of the rate of formation of these compounds, so far it has not been done with perfect satisfaction.

An atomic weight determination of the fraction thus had was made and the value 216 obtained. This showed an approach to 212 of berzelium.

The type-formula of the double luteo salts was obtained by analysis as follows:

$$2\{2[Co(NH_3)_6Cl_3] + 3R(SO_4)_2\} + 3H_2O$$

For the roseo salt,

$$2\{2[Co(NH_3)_5Cl_3] + 3R(SO_4)_2\} + 9H_2O$$

R = Original thorium = 232.5; Carolinium = 258; Berzelium = 212.

The solubility of double luteo salts in water was determined as follows:

Double salt of	berzelium	1 : 2,000 parts.
	carolinium	1 : 4,500 parts.
	original thorium	1 : 5,400 parts.
	new thorium	1 : 5,400 parts.

There was no marked difference in solubility at 100° C.

A NEW METHOD FOR SHOWING THE COMPLEXITY OF THORIUM.

CHARLES BASKERVILLE WITH E. E. RANDOLPH.

Although convinced from numerous chemical reactions of the distinct differences of the easily volatile berzelium chloride and the less volatile carolinium compound, it appeared a possibility that the former of these two bodies might be a readily volatile oxychloride. The oxides had been used in the preparation of the chlorides. It could also be imagined that a thorium compound of a different degree

of oxidation had been produced with consequent difference in conduct of its compounds from the normal tetravalent thorium. To determine this the metallic thorium (99 per cent pure) was subjected to the action of pure dry chlorine without the presence of any oxygen. The total material was converted into the chloride in the apparatus described in the original paper at a temperature of 500°, when no appreciable amount of the volatile portion passed over. The temperature was raised to 860° C., and the residue in the boat so treated three times a week each time—in fact, until no more volatile body was observed. The distillation was carried out with great slowness to avoid, as far as possible, the mechanical transportation of small particles.

A determination of the atomic weight of the residue, after it had been subjected to the usual vigorous treatment for purification, gave the value 241.2. The berzelium portion treated in the same way gave a value, 216.3, assuming both as tetravalent. Efforts so far to determine the molecular weight, that the actual atomic equivalence may be known, have not been successful on account of the dissociation of the product used, or a question as to the actual composition and its freedom from the other constituents.

SOME ORGANIC SALTS OF CAROLINIUM.

CHARLES BASKERVILLE WITH S. JORDAN.

The following organic salts of carolinium have been prepared and examined in part: Formate, acetate, oxalate, lactate, acetyl-acetonate, malate, succinate, citrate, tartrate, and salicylate.

ON THE COMPOSITION OF THORIUM SULPHATE IN SOLUTION.

CHARLES BASKERVILLE AND H. F. SILL.

The specific conductivity of thorium sulphate solutions at 25° C. was determined between the concentrations $\frac{1}{20}$ to $\frac{1}{10240}$ molar, as per the following table:

Dilution.	Specific conductivity.	Dilution.	Specific conductivity.
20	0.00224	640	0.000341
40	.00149	1,280	.000226
80	.00110	2,560	.000148
160	.000744	5,120	.0000688
320	.000506	10,240	.0000442

Ruer (Zeitsch. An. Ch., 42, 87) found that in solutions containing $Zr(SO_4)_2$ and H_2SO_4 in equi-molecular proportions the zirconium

on electrolysis migrates to the anode. From this fact and the data he concluded the existence of a zirconium sulphuric acid in solution, or $H_2 + Zr(SO_4)_3^{--}$.

It was intended to carry out a similar migration experiment with thorium sulphate and sulphuric acid solution, in view of the analogous behavior of zirconium and thorium compounds. The apparatus for the migration experiment not being at hand, it was decided, pending the arrival of the same, to make conductivity determinations on the equi-molecular $Th(SO_4)_2$ and H_2SO_4 solution, it being probable that if a thorium sulphuric acid were formed in any considerable quantity the conductivity of the solutions would deviate widely from that calculated for $Th(SO_4)_2$ and H_2SO_4 acting independently. The results of these determinations are given in the following table:

Dilution.	Specific conductivity.
40	0.0137
80	.00746
160	.00428
320	.00235
640	.00127
1280	.000672

On comparison of these conductivities with those of $Th(SO_4)_2$ and H_2SO_4 separately (the latter were taken from Kohlrausch & Holborn, Leitfahigkeit der Electrolyte), it was found that the values obtained above were somewhat smaller than those calculated, assuming the existence of the H_2SO_4 and $Th(SO_4)_2$ independently of each other in the solution. The variation, however, is not striking, and hence it can not be concluded that any considerable amount of $H_2 + Th(SO_4)_3^{--}$ is formed.

The work will be continued by Dr. Leo F. Guttman on account of the resignation of the junior author.

ATTEMPTS TO PREPARE THORIUM ALKYLS.

CHARLES BASKERVILLE WITH MONY DE MAJO.

If thorium be complex, as indicated by previous work, better methods for the separation of its constituents become desirable. Aside from the interest attending the production of hydrocarbon compounds of the heavy tetravalent thorium, differences in the melting and boiling points of the alkyls of its constituents, if they be prepared, offered a solution to the problem.

A mixture of metallic thorium (50 per cent) and thorium oxide was treated with pure ethyl-iodide. This was done in an atmosphere of carbon dioxide and under a pressure of about 900 mm. of mercury. All materials were dry. No reaction being apparent after heating upon a water bath for several hours, the flask was gently warmed by means of a small flame. The temperature suddenly rose from 70 to 110° C., and an intense red-brown liquid distilled over and a large amount of a heavy brownish-red vapor escaped without condensation. There was much sublimed iodine as well. On heating the bulb higher, no further distillate was obtained. The original mixture was grayish black. The residue was grayish white and undoubtedly a mixture of the original thorium oxide and tetra-iodide. It was thoroughly investigated by the use of organic solvents, potassium hydroxide, etc., to make sure no solid thorium alkyl was present.

The red-brown oily distillate, which was collected at 110° C., was washed with water in which it was only slightly soluble. The water gave a weak iodoform reaction on treatment with iodine and an alkali, as well as a precipitate, indicating a thorium alkyl. Attempts to decompose that portion insoluble in water with fuming nitric acid resulted in violent explosions as soon as the liquids were brought in contact. All the material was lost.

Pending the preparation of more and purer metal, that method was temporarily abandoned. It has been prepared now, so the work may be undertaken again.

Zinc ethyl was prepared, placed in a "shooting tube" with a calculated amount of thorium chloride. All the operations must be carried out in an atmosphere of dried carbon dioxide, entailing much inconvenience and requiring some ingenuity in manipulation. The air was thoroughly washed out of the tube by repeated filling with carbon dioxide and exhausting. The sealed tube was heated to 260° C. for a day. A solid brown-yellow mass was obtained, which yielded nothing to the ordinary organic solvents with which it was treated. On subjecting a portion to dry distillation a drop of a heavy yellow oil was collected. It gave the iodoform reaction when treated with iodine and potassium hydroxide.

An ineffectual attempt was made to prepare thorium-phenyl by utilizing the Grignard reaction, as follows: Brombenzol and magnesium ribbon, in calculated amounts, were placed in ether which had been dried over metallic sodium. After the magnesium had been dissolved the calculated amount of thorium chloride was added and heated for hours. It is deemed unnecessary to give the details of the further treatment and examination.

ON THE CONDUCT OF PURE THORIUM COMPOUNDS WITH CERTAIN SULPHONIC ACID SALTS.

CHARLES BASKERVILLE WITH MONY DE MAJO.

Nieszytka* has prepared naphthaline sulphonic salts of cerium. Organic reagents have been used successfully in separating certain of the metallic elements, for example, nitroso-β-naphthol has been used for iron and cobalt and chromotropic acid for the detection of titanium.

The conduct of pure thorium compounds with the sodium salts of naphthaline and benzol sulphonic acids demanded attention. Two apparently distinct fractions were had when soluble pure thorium nitrate solutions were precipitated with sodium naphthaline sulphonate. One of the portions gave a distinctly gelatinous precipitate, while from the filtrate there was separated by evaporation excellent crystals. The precipitate on treatment with an excess of the sulphonated salt did not go into solution. On analysis, after drying under similar circumstances, the two extremes gave 30 per cent, then 27.3 per cent, and the other fraction gave 43.5 per cent residue after ncineration.

On the reconversion of these fractions into the nitrates, the process was repeated several times. After the third treatment that portion which was readily precipitated came down in a very bulky gelatinous mass, while the soluble portion was not precipitated at all. The variations in these reactions were not seriously affected by dilution or heat. Not only was a distinct separation thus obtained, but in the course of the purification of the extremes one gave a black body on ignition. When treated with sulphuric acid it became white, but turned dark as soon as water was added. It corresponded in its reactions with none of the known chemical elements except thorium, and differed from it materially in a number of ways. We are preparing more of the material by the same process, which is most time-consuming, three months being required for the separation reported.

The conduct with benzol-sulphonic salts was quite similar.

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*Inaugural Dissertation, Friederichs Universitäts, Halle, Wittenburg.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. Grant No. 154. *Research upon the atomic weight of manganese.* (For first report see Year Book No. 3, p. 105.) $500.

Abstract of Report.—Four samples of manganous bromide were prepared. In the case of samples A and B, the manganese was freed from other metals by crystallization of potassium permanganate, this operation being performed thrice with sample A and ten times with sample B. After reduction with sulphur dioxide, both samples were converted into bromide by precipitation with ammonium carbonate, solution of the carbonate in nitric acid and crystallization of the nitrate, reprecipitation with ammonium carbonate in platinum, and finally solution in hydrobromic acid in a quartz dish. Bromine was expelled from the solution by heating in quartz, and the bromide was several times recrystallized in platinum.

Samples C and D were obtained from commercial manganese dioxide and manganous sulphate. Purification was effected by fractionation with hydrogen sulphide and sodium hydroxide. The manganese was converted into bromide as in the case of samples A and B.

After fusion in a stream of nitrogen and hydrobromic acid gases in a platinum boat, the bromide was dissolved and precipitated with a weighed equivalent amount of the purest silver. The exact end-point was found, and then the silver bromide was collected and weighed.

ABSTRACT.

SERIES I.—$MnBr_2 \cdot 2Ag$.

[Ag 107.930, Br – 79.955.]

Number of analysis.	Sample of $MnBr_2$.	Sample of Ag.	Weight of $MnBr_2$ in vacuum.	Weight of Ag. in vacuum.	Atomic weight of Mn.
			Grams.	*Grams.*	
1	A	C	6.53745	6.56755	54.961
2	A	C	4.81006	4.83238	54.953
3	C	C	4.88098	4.90354	54.957
4	C	A	5.63220	5.65813	54.961
5	C	B	6.58985	6.62041	54.954
6	A	A	5.79926	5.82600	54.959
7	B	A	4.19912	4.21839	54.964
8	A	B	3.59811	3.61478	54.954
9	B	B	5.16335	5.18711	54.961
10	B	C	3.92227	3.94045	54.954
11	B	C	4.49159	4.51250	54.950
12	C	A	3.60073	3.61736	54.958
13	D	A	4.77393	4.79619	54.948
14	D	B	3.57660	3.59319	54.953
15	D	A + B	5.69973	5.72641	54.944
Average					54.955

SERIES II.—$MnBr_2$:2AgBr.

Number of analysis.	Sample of $MnBr_2$	Weight of $MnBr_2$ in vacuum.	Weight of AgBr in vacuum.	Atomic weight of Mn.
		Grams.	*Grams.*	
16	A	5.58418	9.76578	54.959
17	A	5.63433	9.85362	54.956
18	A	6 53745	11.43318	54.954
19	A	4.81006	8.41223	54.953
20	C	4.88098	8.53658	54.945
21	C	5.63220	9.85025	54.949
22	C	6.52627	11.41309	54.964
23	A	5.79926	10.14223	54.953
24	A	3.59811	6.29286	54.946
25	B	5.16335	9.02975	54.961
26	B	3.92227	6.85984	54.945
27	B	4.49159	7.85587	54.936
28	C	3.60073	6.29731	54.951
29	D	4.77393	8.34919	54.919
30	D	3 57660	6.25572	54.930
31	D	5.69973	9.96845	54.947
Average	....	....	....	54.950

Average, rejecting analysis 30 .... 54 951
Average of Series I and II 54 953

			$MnBr_2$:2Ag.	$MnBr_2$:2AgBr.
Average of analyses with—				
Sample	A of	$MnBr_2$	54.957	54.954
	B	$MnBr_2$	54.957	54.947
	C	$MnBr_2$	54.958	54.952
	D	$MnBr_2$	54 948	54.948
	A	Ag	54.958	
	B	Ag	54.956	
	C	Ag	54.955	

The close agreement of the averages of Series I and II and of the averages of analyses with different samples of material leaves no doubt that the atomic weight of manganese lies very near the average of Series I and II, 54.953 (Ag = 107.930).

Gomberg, Moses, University of Michigan, Ann Arbor, Michigan. Grant No. 153. *Study of triphenylmethyl and analogous compounds.* (For first report see Year Book No. 3, page 106.) $500.

Abstract of Report.—Work under this grant was carried on with the assistance of Dr. L. H. Cone. The influence of sunlight upon solutions of triphenylmethyl was first investigated, as this influence was found to be a disturbing factor in all our work. It was found that in presence of certain solvents triphenylmethyl is reduced under the influence of light to triphenylmethane. All our further work was therefore carried on in absence of sunlight. A complete study of the combinations of triphenylmethyl with the different classes of

oxygen compounds was made. It was established that it combines with nearly all esters, ethers, and ketones, forming definite compounds of uniform composition. The reactivity of triphenylmethyl was found to be so great that the latter entered into combination also with nitriles, with unsaturated aliphatic hydrocarbons, with aromatic hydrocarbons, with chloroform, carbon disulphide, and even with some saturated aliphatic hydrocarbons. The results of the above investigation were published in three papers in the Ber. d. deut. chem. Ges., vol. 37 and 38.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 267. *Investigations on hydrates in concentrated aqueous solutions.* (For previous reports see Year Book No. 2, p. xxx, and Year Book No. 3, p. 106.) $1,000.

The work during the past year on the hydrates formed by salts, acids, and bases, when dissolved in water, has had to do more especially with the determination of the composition of the hydrates. Although certain assumptions are necessary in calculating from experimental data the composition of these hydrates, yet it is very probable that the approximate composition has been settled in a large number of cases. The general relation has been established, that the total amount of water held in combination by the dissolved substance increases with the concentration of the solution. There are very few exceptions to this relation. The number of molecules of water combined with one molecule of the dissolved substance generally increases with the dilution, from the most concentrated to the most dilute solution investigated. In the case of certain acids, however, the number of molecules of water in combination with one molecule of the acid passes through a maximum. A suggestion to account for this apparent discrepancy, which is in accord with the law of mass action, has been proposed. Most of the organic compounds show little or no power to combine with water. Glycerol and cane sugar, however, are exceptions.

The conclusion has been reached that both molecules and ions combine with water. The fact that certain non-electrolytes show marked hydration proves that molecules can combine with water, since in such solutions there are no ions. Electrolytes generally show the greatest hydration in the most dilute solutions, which proves that ions can combine with water; since in such solutions there are practically no molecules, but only ions present.

The present theory of hydrates differs fundamentally from the older theory of Mendeléeff. According to the latter, certain dissolved

substances can combine with water, forming a few compounds of perfectly definite composition. According to the theory of hydrates here advocated, a dissolved substance combines with water, forming a series of hydrates having all possible amounts of water up to a certain maximum quantity, the composition of the hydrates for any given substance being conditioned by the concentration of the solution, as we would expect from the law of mass action. It has been demonstrated by the boiling-point method that solvents like methyl and ethyl alcohols can also combine with the dissolved substance.

The conclusions thus far reached are based upon a study of about 100 compounds, including salts, acids, bases, and neutral organic compounds. The freezing-points, conductivities, and specific gravities of about 1,500 solutions have been determined and the refractivities of a large number have been measured.

The bearing of this work on the general theory of solutions is obvious. The fact that a part of the water is combined with the dissolved substance and is not acting as solvent must be taken into account in dealing with all solutions, and especially with concentrated solutions. This accounts in large part for the abnormal behavior of concentrated solutions, and is doubtless the chief reason why the laws of gas pressure do not apply to the osmotic pressure of such solutions.

When the above facts are taken into account, together with such factors as appear in Van der Waals's equation for gases, it will probably be shown that the gas laws apply to the osmotic pressure of concentrated solutions, measured under comparable conditions with gas pressure, as well as to concentrated gases.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 238. *On the measurement of osmotic pressure.* (For previous reports see Year Book No. 2, p. xxx, and Year Book No. 3, p. 108.) $1,500.

Abstract of Report.—By the middle of the past year so much progress had been made that several cells of ideal excellence for the measurement of osmotic pressure were ready for service, and with them the determination of the pressure which is exerted by cane sugar in aqueous solution was undertaken. The pressure of thirteen concentrations, varying from 0.05 to 1.00 gram-molecular weight of sugar dissolved in 1,000 grams of water, has been satisfactorily measured, and it is believed that the results throw an entirely new light upon

the subject of osmotic pressure. The view hitherto held regarding this force has been authoritatively expressed in the following words: *Dissolved substances exert the same pressure, in the form of osmotic pressure, as they would exert were they gasified, at the same temperature, without change of volume.*

It was known, however, that only very dilute solutions conform to this rule—that in concentrated solution the pressures are much higher than can be accounted for by it.

The final success of the long-continued efforts to solve the problem of the production of a serviceable cell has made it impossible to measure the pressure of all concentrations of solutions with considerable precision, and the first results obtained indicate that the pressure of concentrated solutions are not less *normal* than those of dilute solutions, provided certain relations hitherto misapprehended are taken into account.

The rule which is deduced from the results of the measurements which have been made is as follows: Cane sugar dissolved in water exerts an osmotic pressure equal to that which it would exert if it were gasified at the same temperature *and the volume of the gas were reduced to that of the solvent in the pure state.* In other words, the dissolved substance exerts throughout the *larger volume of the solution* an osmotic pressure equal to the pressure which it, as a gas, would exert if confined to the *smaller volume of the pure solvent.*

The most concentrated solutions conform to this rule, as well as do the most dilute, and all concentrations which have thus far been tested are in satisfactory agreement with it.

Some work has also been done upon the supposed abnormal freezing points of concentrated solutions of cane sugar, and it appears that, if the relations which have been found to hold for the osmotic pressure of such solutions are taken into account, the abnormalities of freezing-point depression disappear in the sense that all concentrations conform to the same rule.

The measurement of osmotic pressure will now be extended as rapidly as possible to solutions of other substances, in order to determine whether the relations discovered in the case of cane sugar are of a general character.

Noyes, A. A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 239. *Researches upon (1) Electrical conductivity of salts in aqueous solution at high temperatures; (2) Ionization of weak acids and bases and hydrolysis of their salts in aqueous solution at high temperatures; (3) Transference determinations in aqueous solutions.* (For previous reports see Year Book No. 2, p. xxxi, and Year Book No. 3, p. 109.) $2,000.

These three researches have been continued during the past year in the Research Laboratory of Physical Chemistry of the Massachusetts Institute of Technology. The first has been executed with the assistance of Dr. William D. Coolidge and Mr. Arthur C. Melcher; the second with that of Mr. Yogoro Kato and Mr. Robert B. Sosman, and the third with that of Mr. Edward W. Washburn and Mr. Ralph S. Gifford. The work upon all these investigations has progressed so far that a series of ten articles describing fully the methods and results will soon be submitted to the Carnegie Institution of Washington for publication.

Since the report was made a year ago the work done upon the first investigation, on the electrical conductivity of aqueous solutions at high temperatures, has consisted in the extension of the measurements previously made with silver nitrate, potassium sulphate, and barium nitrate at temperatures up to 218° to the still higher temperatures 281° and 306°. By the results of these measurements the conclusions stated in the previous report in regard to the effect of temperature on the ionization of substances and the migration velocities of ions have been more fully confirmed. It has been found especially that the decrease of ionization becomes extremely rapid at the highest temperature interval investigated—that is, between 281° and 306°. In order to extend the measurements up to and through the critical temperature, a radical modification of the conductivity apparatus is necessary, since thorough agitation, measurements at a series of small temperature-intervals, control of the pressure upon the solution, and resistance of the apparatus to a much higher pressure must be provided for. Much progress has already been made in adapting the apparatus to these conditions, and it is hoped that it will be entirely perfected during the coming year.

The second research on the ionization of weak acids and bases and the hydrolysis of their salts has been continued by measuring the conductivity of ammonium hydroxide and acetic acid at a series of temperatures up to 218°, and studying the hydrolysis of ammonium acetate at 100°, 156°, and 218° by the method described in the preced-

ing report, which consists in determining the increase produced in the conductivity of the salt by the addition to it of one of its hydrolytic products, acetic acid or ammonium hydroxide. The results obtained show that the ionization of both the acid and base diminishes greatly with rising temperature, while that of water increases enormously between 18° and 100° and largely between 100° and 156°. Thus the value of the ionization-constant of water (the product of the concentrations of the free hydrogen and hydroxyl ions present in it), which had been found to be 0.6×10^{-14} at 18° by previous investigators, is shown by these new measurements to be 49×10^{-14} at 100° and 221×10^{-14} at 156°. These two opposite variations in the ionization of weak acids and bases on the one hand and in that of water itself on the other reinforce each other in producing increased hydrolysis at high temperatures and make it an important factor even in the case of salts which scarcely exhibit it at all at ordinary temperatures. This is well illustrated by ammonium acetate itself, which at 0.1 normal concentration is hydrolyzed 0.4 per cent at 18°, 4.8 per cent at 100°, 18.3 per cent at 156°, and about 50 per cent at 218°.

The third research on electrical transference in aqueous solutions has been prosecuted in a new direction, with the view of determining the extent to which ions are hydrated. The hydration of substances in solution is one of the most important, as well as one of the most difficult, of the unsolved problems connected with the theory of solutions. In the case of ions it is possible to determine to what extent water migrates with them by making accurate transference determinations in the presence of a non-migrating substance, like cane-sugar. During the past six months the details of an experimental method have been worked out, by which it is hoped to obtain conclusive results in regard to the hydration of some of the more important ions.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grant No. 240. *Investigation of the value of atomic weights, etc.* (For previous reports see Year Book No. 2, p. xxxii, and Year Book No. 3, p. 112.) $2,500.

Abstract of Report.—Five researches were conducted under the direction of Prof. Richards with the support of this grant, as follows:

(1) An investigation of the atomic weights of sodium and chlorine carried on with the assistance of Dr. Roger Clark Wells. This investigation has been finished, with satisfactory results of unusual completeness, and the results have been published in a monograph of 70 pages (Carnegie Institution Publication No. 28). The final results,

corrected for all discoverable sources of error, are Na = 23.006 and Cl = 35.470, if Ag = 107.920.

(2) A continuation of the study of the compressibility of elements and simple compounds carried on with the assistance of Dr. Wilfred Newsome Stull. The earlier results of Richards and Bonnet were confirmed and the compressibilities of a majority of the chemical elements were determined. Besides affording interesting evidence concerning the significance of atomic volume, these results add weight to the Mendeléev-Meyer classification of the elements, showing well-marked periodicity. In addition to these data, many compressibilities of simple compounds were determined, all of which agree with the predictions of the recent theory of compressible atoms. The method of Richards and Stull (Carnegie Institution Publication No. 7) continued to give satisfaction. The experimental work has reached a stage demanding further publication and is now being codified and described for this purpose.

(3) An investigation of the effect of pressure and strain upon the electromotive force of pure iron immersed in solutions of its salts, carried on with the assistance of Gustavus E. Behr, jr. This investigation afforded conclusive evidence concerning the effects of pressure, temperature, and the occlusion of hydrogen upon the electromotive force, and therefore upon the tendency of iron to rust. The work of C. Hambuechen was conclusively disproved. The results have a practical bearing as well as considerable theoretical interest, and will be described for publication as soon as possible.

(4) A research upon the electromotive force of cells composed of amalgams of different strengths, carried on with the assistance of Dr. George Shannon Forbes. This investigation needs only a few more weeks of experimental work for its completion, and is already in part in form for publication. The plan is comprehensive, including (*a*) the determination of the deviations of the electromotive forces from those demanded by the gas law, (*b*) the heat of dilution of the amalgams, (*c*) the heat capacities of the amalgams. Both zinc and cadmium amalgams were studied, and results of great consistency and precision were obtained. The interest of this work lies mainly in its relation to the theory of thermodynamics; the details are too complex for brief presentation. As soon as possible this work also will be published.

(5) The determination of the specific heats of certain systems over wide ranges of temperature, carried on with the assistance of Gustavus E. Behr, jr., and Richard Fay Jackson. This work is in its

earlier stages; it will be greatly helped by the large liquid-air plant of improved construction now being installed by the chemical laboratory.

A considerable balance of the grant still remains. This will be used during the coming winter in the prosecution of investigations 2, 4, and 5, and especially in the determination of several other atomic weights with the greatest possible precision.

Tingle, J. Bishop, Johns Hopkins University, Baltimore, Maryland. Grant No. 40. *Investigation of derivations of camphor and allied bodies.* (For first report see Year Book No. 2, p. xxxiii.) $500.

Dr. Tingle's work will be continued for some time. He presents the following abstract of a paper on "Condensation Compounds of Camphoroxalic Acid and Amines," which appeared in the American Chemical Journal, vol. 34, page 217 (1905).

Camphoroxalic acid yields three classes of metallic salts, those in which the carboxyl group is affected, those in which the hydroxyl hydrogen is replaced, and those in which both hydroxyl and carboxyl participate. They are represented by the formulæ

$$C_8H_{14}\left\langle\begin{array}{l}C:COHCOOM\\ |\\ CO\end{array}\right. \qquad C_8H_{14}\left\langle\begin{array}{l}C:COMCOOH\\ |\\ CO\end{array}\right. \qquad C_8H_{14}\diagdown\begin{array}{l}C:COMCOOM\\ |\\ CO\end{array}$$

respectively, where M equals one atom of a monovalent metal. The salts of silver, barium, and calcium belong to the first class, that of ferric iron to the second, while copper forms a salt of the third type. This last class of salts is believed to be entirely without analogy; no compounds of similar structure have ever been described.

Camphoroxalic acid condenses with a number of amines. One of the objects of this investigation was to endeavor to ascertain the limits of the reaction and the cause of its inhibition in certain cases. Three classes of compounds have been obtained from camphoroxalic acid and certain amines, viz, acids of the type $C_8H_{14}\left\langle\begin{array}{l}C:CCOOH\\ |\quad NHR\\ CO\end{array}\right.$, salts of these acids, such as $C_8H_{14}\left\langle\begin{array}{l}C:CCOONH_3R\\ |\quad NHR\\ C\end{array}\right.$, and compounds of the formulæ $C_8H_{14}\left\langle\begin{array}{l}C:CH\\ |\quad NHR.\\ C\end{array}\right.$ (R=a hydrocarbon radical.)

Some amines form compounds of all three types; other amines only yield derivatives belonging to one or two. The amines which react in this manner are α- and β-naphthylamine, meta- and para- toluidine,

benzylamine, methylamine, and nitrotoluidine. Diethylamine and dimethylamine yield compounds resembling the second of the above classes, but containing the elements of an additional molecule of water. Interesting derivatives were also obtained from benzamidine and benzidine. Several compounds were prepared from semicarbazine, but their constitution has not yet been fully worked out. The action of acylating agents on certain of the substances described in the paper was also investigated. The results confirm the formulæ for them which were previously regarded as being the most probable. A number of amines entirely failed to react with camphoroxalic acid; evidence is being sought as to the cause of this behavior.

Washington, Henry S., Locust, New Jersey. Grant No. 95. *Chemical investigation of igneous rocks.* (For first report see Year Book No. 3, p. 113.) $1,200.

Abstract of Report.—Since submitting his last report Dr. Washington has continued his chemical work on the rocks of the Bolsena-Vesuvius line of volcanoes, and has made fifty complete chemical analyses in accordance with the plan previously outlined. Along with this a careful microscopic study of the rocks was undertaken, involving very numerous measurements of the quantitative mineralogical relations in thin section. The observations and the conclusions to be drawn from these chemical and miscroscopical studies have been embodied in a monograph.

In May Dr. Washington sailed for Gibraltar, visited Madrid first, and then proceeded to Gerona and Olot, where a detailed study of the complex of small volcanoes of this little-known region was made and an ample collection of the various occurrences gathered for future study with the microscope and by chemical analysis. The visit to the region also enabled him to gain an insight into the general structure of the volcanic district which has hitherto been somewhat obscure.

After the completion of his examination of the Olot district, he visited the locality of the so-called corsite (Kugeldiorit) in the southern part of Corsica. Specimens of the rock of this locality are to be found in most collections, but no modern study of it has yet been made. The occurrence is small in extent, but abundant material was collected for future microscopical and chemical study, which it is hoped will throw some light on the origin of this peculiar rock texture, of which few examples are known.

After a journey to the north of Italy he visited Rieti in the Abruzzi, where an intrusive rock of a very exceptional character occurs. Of this peculiar rock little is known and no good analysis exists. The

material collected here will certainly prove to be of very great interest, the rock being almost, if not quite, unique in its character.

After a short stay in Sicily, where the extreme heat precluded the hoped-for collection of the rocks of Mount Etna, the island of Pantelleria was visited. Here a representative collection was made of the various interesting lavas for which this island is celebrated and which will well repay investigation along modern lines. An excursion was also taken to the small volcanic islet of Linosa, of which the rocks, largely basaltic, have never been described. Near Tunis, the next locality visited, the so-called volcano of Boukoumine was studied, resulting in the discovery that it is not a volcano, being composed entirely of limestone.

From Tunis he passed over to Sardinia. Here extensive and thoroughly representative collections were made of the varied and extremely interesting rocks of the large volcano of Monte Ferru, as well as of the heretofore undescribed trachytic and basaltic sheets and small, recent basaltic cones which extend as far north as Sassari. A reconnaissance of the petrographically unknown volcano of Monte Arci, south of Monte Ferru, was also undertaken and representative collections were made. Later, collecting was done at the Berici Hills, near Vicenza, for the purpose of collation of these basalts wlth the rocks of the neighboring Euganean Hills, from which extensive material had been obtained in former years.

Dr. Washington returned to America in November. He thinks that several years' work, devoted especially to chemical analysis, will be required to describe satisfactorily the material which has been collected.

ECONOMICS AND SOCIOLOGY.

REPORT OF THE DIRECTOR OF THE DEPARTMENT.*

BY CARROLL D. WRIGHT.

In the report of this department, as printed in Year Book No. 3, 1904, I presented so fully the details of the division of work and of what was being done that it does not seem advisable to repeat these features.

There has been a change in collaborators in the division relating to Manufactures, originally under the charge of Hon. S. N. D. North, Director of the Census, and in Transportation, under Prof. William Z. Ripley, of Harvard University. At the request of the collaborators, I took over the work of the Division of Manufactures, and at a like suggestion Prof. B. H. Meyer, of the University of Wisconsin, who had been aiding Professor Ripley, took over the work of Transportation. The work under all the divisions is now being vigorously prosecuted and with gratifying results. Some additional statements to those made last year may be of interest.

DIVISION I.—POPULATION AND IMMIGRATION.

Prof. Walter F. Willcox in charge has brought out certain reports of great value to this division, under the auspices of the Census Bureau, and for which the Carnegie Institution of Washington has incurred no direct responsibility or expense. The publications are:

Census Bulletin No. 4. Discussion of Increase of Population.
8. Negroes in the United States.
14. Proportion of the Sexes in the United States.
22. Proportion of Children in the United States.
23. Census Statistics of Teachers.

An article on the "Probable Increase of the Negro Population of the United States," in the Quarterly Journal of Economics for August, 1905.

The index to Niles Register, to which allusion was made last year, and the index to the material in Cornell University have been completed, as well as a careful study of the history of Federal legislation on the subject of immigration.

The study of the history of Russian immigration is by a Russian Jew of education and ability, Mr. E. A. Goldenweiser.

The study of the history of immigration from Austria-Hungary to the United States has been progressing satisfactorily. Miss E. G.

* Grant No. 222. $30,000 for investigations relative to an economic history of the United States. (For first report see Year Book No. 3, pp. 55-64.)

Balch has spent nearly a year in that country, visiting the main regions from which immigrants come, conferring both with the officials who have knowledge of the subject and with peasant friends and relatives of the emigrants.

The history of Chinese immigration to the United States, being prepared by Prof. Mary Roberts Smith as a Carnegie research assistant, is approaching conclusion.

All these matters and others that will be taken up, some of which are in course of preparation, disclose the influence of population and immigration upon the economic development of the country.

Division II.—Agriculture and Forestry, including Public Domain and Irrigation.

Prof. Kenyon L. Butterfield, in charge, employed Prof. Frank W. Blackmar, of the University of Kansas, to study the economic and social influence of irrigation in this country. Twelve systems of irrigation have been investigated and valuable information gained about others. Professor Blackmar's methods of investigation are to examine the water capacity, methods of tillage, condition of social life, value of crops, prices, transportation, educational and religious conditions, and other elements arising from systems of irrigation and showing the economic development resulting therefrom.

Mr. A. E. Sheldon, of Lincoln, Nebraska, director of field work of the Nebraska Historical Society, is investigating the "history of land systems and land policies in Nebraska," and in this connection is conducting personal interviews with Sioux, Ponca, Omaha, Pawnee, Otoe, Missouria, and Northern Cheyenne tribes. Representatives of the tribes have been personally interviewed and notes taken on the spot.

Prof. R. H. Leavell, of the Mississippi Agricultural College, is investigating "The race factor in the history and status of agriculture" in this State. This work is progressing satisfactorily. From a sociological sense, Professor Leavell will investigate the conditions of the economic life, the family, and general social life; also the signification of the relations between the races in various phases.

Mr. George Frederick Wells, B. S., is studying matters in connection with New England churches.

Prof. Ernest Burnham, of the Western State Normal School, Kalamazoo, Michigan, is investigating the educational conditions of rural communities in Kalamazoo County, Michigan. He is assisted in this work by men under the immediate direction of the State

superintendent of education. This investigation has for its purpose the showing of—

a. The origin, evolution, and present status of common-school ideals as found in the intensive study of a typical unit of rural territory in Michigan.

b. The exact educational history in detail of every child of school age in the distinctly rural school districts of the chosen unit of territory for a given school year.

c. The academic, professional, and character qualifications of the teachers in the distinctly rural schools of the chosen unit of territory.

d. The area, valuation, rate of school tax, condition of school property and equipment, educational standards, and coöperative social activities of the distinctly rural common-school districts of the chosen unit of territory.

e. The effect upon local and general public educational sentiment and activity of the publication in tabulated detail and proven summaries of the fundamental facts determining the educational opportunities of the children of distinctly rural communities.

All these points will show distinctly the movement in an agricultural territory toward better farming methods and the relations of the farming population to economic development.

President Butterfield is also conducting an inquiry through Prof. J. E. Pope, of the University of Missouri, into the history and status of the economic and social relations of the agricultural industry of that State, while Prof. T. N. Carver, of Harvard University, is investigating the economic characteristics of the agricultural industry; and Mr. Charles S. Potts, of the State Agricultural College of Texas, is investigating the economic and social relations of the agricultural industry in the Brazos Valley, Texas.

Division III.—Mining.

Mr. Edward W. Parker reports much progress by chapters concerning the mining industry, having at his command the very best opportunities for his investigation in addition to the specific studies which he is conducting. These relate to a very vigorously pushed work relative to iron-ore mining, by Prof. C. K. Leith, of the University of Wisconsin, and a history of the copper-mining industry, by Dr. M. N. Bolles, Columbia School of Mines; lead and zinc, by Mr. Walter Renton Ingalls, of New York City, one of the recognized authorities on the mining and metallurgy of lead and zinc; precious metals, by Mr. J. F. McClelland, associate professor at Columbia

School of Mines; a history of anthracite, by Mr. H. H. Stoek, editor of Mines and Minerals, Scranton, Pennsylvania. Mr. Stoek has completed a large part of his work and hopes to put it all in shape in the near future. The history of bituminous coal mining is in charge of Prof. W. S. Landis, of Lehigh University, Bethlehem, Pennsylvania, who has submitted the manuscript of his report and also chapters on the history of manganese mining in the United States and the history of chromium.

The subject of petroleum and natural gas is in charge of Prof. G. P. Grimsley, assistant state geologist, West Virginia University, Morgantown, West Virginia. He is now completing the collection of data and arranging the material; he has also arranged quite an extensive bibliography in his division of work.

Mr. F. B. Laney, of the University of North Carolina, is conducting an inquiry as to building stones and quarrying.

The history of the clay industry in the United States is being prepared by Dr. Heinrich Ries, professor of economic geology, Cornell University.

Edwin C. Eckel, U. S. Geological Survey, Washington, District of Columbia, has charge of the investigation concerning cement and cement materials.

The subject of abrasive materials, rare earths, gems, and mica is in charge of Dr. Joseph Hyde Pratt, University of North Carolina, who reports that his chapter is nearly ready for transmittal, while the work on rare metals is well under way, with the exception of the literature on the subject.

The history of the development of chemical minerals is under the charge of Prof. Charles E. Munroe, George Washington University, Washington, District of Columbia. Professor Munroe is treating the subject assigned him with rare ability, and is also conducting the preparation of a chapter on the influence of chemistry on the mining industry of the United States.

"The minor minerals" is a subject being treated by Mr. Ira A. Williams, of the Iowa State College. He has collected much material and his progress is satisfactory.

Division IV.—Manufactures.

As stated, I took over the work of this division from Mr. North, and this necessitated some delay, but all the work outlined in the last Year Book is being carried on now and will be pushed during the winter, with the assistance of Dr. Victor S. Clark.

Division V.—Transportation.

Prof. B. H. Meyer, one of the railroad commissioners of Wisconsin, who had assisted Professor Ripley originally in charge of the division, is now in full charge, but the change caused some delay. During the past year Mr. Meyer employed Mr. R. J. Usher, a student of the University of Wisconsin, to collect notes on the basis of which the Congressional history of railroads could be written.

Dr. G. G. Tunell, now with the Atchison, Topeka and Santa Fe Railway, has undertaken to prepare the history of commerce and transportation on the Great Lakes, while Dr. F. A. Cleveland, of New York, is actively engaged in assisting Professor Meyer. Much progress has been made in the collection of literature and official data, but the collection of original material has not progressed very far.

Division VI.—Domestic and Foreign Commerce.

During the past year seven men have been assisting Prof. Emory R. Johnson in charge of the division.

Prof. J. Russell Smith has completed his monograph on the organization of ocean commerce, and it was published early in 1905 by the University of Pennsylvania with due acknowledgment of the aid received from the Carnegie Institution of Washington. Since the publication of that monograph Professor Smith has been rounding out the historical portions of his investigation by making a study of the history of line and charter traffic, history of the relations of rail and water carriers, and history of combination and consolidation of ocean carriers.

The history of the consular service as relating to commerce has been completed practically by Mr. Chester Lloyd Jones.

Mr. Walter Sheldon Tower and Prof. Raymond McFarland are working upon the history of American fisheries. Professor McFarland has submitted the first two sections of his manuscript.

The study of the commercial legislation of the American colonies in the United States has been undertaken by Mr. Albert A. Giesecke. He has examined the commercial legislation of each of the thirteen colonies during their entire history up to 1789. He has also studied and charted the main provisions of the legislation of the colonies.

The work upon the history of the coastwise commerce of the United States, being prepared by Mr. Thomas Conway, jr., has made substantial progress during the year.

The subject of marine insurance has been treated in a monograph of about 25,000 words by Dr. S. Huebner. This monograph has been published by the American Academy of Political and Social

Science as a part of the September issue of the Annals of that society. Dr. Huebner has continued his study of the history of the foreign trade of the United States and has collected a large amount of valuable material. This is the largest and most important division of the general history of American commerce, and he may require another year to complete his work.

In accordance with the division of the field agreed upon between Professor Ripley and Professor Johnson, that he, Professor Ripley (Professor Meyer is now in charge), should be responsible for the history of our domestic inland commerce, and that Professor Johnson should work up the subject of ocean transportation, Professor Johnson has been engaged particularly during the last three months upon the history of ocean transportation.

DIVISION VII.—MONEY AND BANKING.

Prof. Davis R. Dewey, in charge, reported last year that the chief stress up to that time had been placed upon indexing, etc. During the past year subjects of investigation have been assigned as follows:

Mr. E. H. Davis, Purdue University, a study of local banking in Indiana.
Dr. Adolph Eliason, Minnesota, banking in Minnesota.
Prof. I. A. Loos, Iowa, banking in Iowa
Mr. C. C. Huntington, Ohio, banking in Ohio.
Dr. W. C. Mitchell, California, economic consequences of the greenback issue.
Prof. Jesse E. Pope, Missouri, banking in Missouri
Prof. Charles Lee Raper, North Carolina, banking in North Carolina.
Mr. David L. Wing, Bureau of Corporations, Washington, D. C., greenback party in Maine.
Dr. A. A. Young, Wisconsin, banking in New Hampshire.

These investigators have been furnished with bibliographical references, and by means of Dr. Dewey's preliminary cataloguing have been able to keep in touch. None of these investigations has as yet been completed, but finished chapters may be expected within a few weeks. Dr. Mitchell's work is nearly completed, and he is preparing a detailed statement of the object of his inquiry and reports progress. The work done so far comprehends (1) the gold price of the paper dollar; (2) rates of exchange in New York upon London and Paris; (3) wholesale prices; (4) retail prices; (5) wages, and also the relation of rates of interest to banking.

Dr. Dewey reports that he experiences embarrassment in finding men of proper qualifications who have the requisite amount of time at their disposal for carrying on the work. His own services have been devoted to the collection of material for a History of Banking in Massachusetts, and he has the coöperation of Professor Gardner in securing an index to State documents, to which reference will be made later on.

Division VIII.—Labor Movement.

This division, under my own personal charge, is making commendable progress. Dr. Jacob H. Hollander is in charge of the elements or phases of trades unions. A topical analysis of all labor laws of the United States is being made, its object being to secure a concrete statement of the principles of the labor laws of the different States without giving the text.

Miss Edith Abbott, of the University of Chicago, is at work upon the hours of labor, child labor, and women's work, the latter being conducted in conference with Professor Farnam, under his division.

There has also been a division of service in this department by association with Professor Farnam, so as to avoid complications. I think the work of this division will be completed at as early a date as any other, perhaps.

Division IX.—Industrial Organization.

Prof. J. W. Jenks, of Cornell University, in charge, has assigned the history of corporation law to Prof. Horace L. Wilgus, of the University of Michigan. Professor Jenks, for the present at any rate, will do most of the work in connection with his division, securing the aid of helpers, graduate students, and others.

Mr. E. W. Pettibone, who has been investigating the subject of farmers' associations, has made a very careful report on coöperative cheese factories and creameries. He has a study on farmers' organizations for the control of the milk supply nearly ready to publish.

Mr. W. L. Whittlesey has already done considerable work on the subject of the organization of quasi-public industries in cities, such as street railways, gas and electric lighting, etc., with the expectation that the report will be ready within the next few months. Brief reports have been made on several subjects in connection with the beginnings of industries in colonial times and in the early days of the Republic. Among these subjects may be mentioned:

Productive coöperation, by A. A. Freedlander.
Life insurance in the State of New York, by R. J. Halpin.
House industries, by Caroline E. MacGill.
Early trading companies in America, by P. S. McGuire.

Mr. J. N. Lorenz has made a rather full digest of the laws affecting industrial organization in New York in colonial times, while Mr. A. C. Muhse has prepared a careful study of the interrelations between the banks and trust companies of New York City. Mr. C. C. Huntington has prepared a report on the industrial legislation in Ohio down to the time of the civil war, with special reference to the organization of banking.

Professor Jenks has arranged with Professor Johnson to have one of his assistants who is studying internal commerce make a special report on the organization of the grain-handling business, especially as shown in the elevators, and their relations one with another and with produce exchanges and carriers. Professor Jenks is also working in conference with Professors Johnson and Gardner on subjects that interlap with their special work. Professor Jenks was in the far East when the work of the Department of Economics and Sociology was taken up, and it was only after much delay that he was able to begin active operations.

Division X.—Social Legislation.

Prof. H. W. Farnam, of Yale University, informs me that Mr. George G. Groat has completed his study of the law relating to combinations in New York State, and that it was published last summer as No. 3, Vol. XIX, of the Columbia University studies, Trade Unions and the Law in New York.

Miss Belva M. Herron is at work under Professor Farnam on a study of the labor legislation of Illinois, and Mr. Nathaniel F. Soderberg on the labor legislation of Minnesota.

Prof. J. L. Barnard is completing an investigation relative to the factory laws of Pennsylvania, and Prof. J. E. Hagerty, of the Ohio State University, is investigating the poor laws of his State.

Mr. W. M. Adriance, a graduate student in Yale University, is working on the operation of the mining laws of Pennsylvania and has collected considerable material.

Dr. F. R. Fairchild has made a study of the New York factory laws, which is to be published by the American Economic Association.

As stated in Labor Movement, Professor Farnam is coöperating with me in these matters, which in some respects belong to each of us.

Division XI.—Federal and State Finance, including Taxation.

Prof. Henry B. Gardner, in charge, has devoted his attention particularly to the question of State and local finance, which is a field not hitherto worked. During the past year provision has been made for a study of the financial history of the individual States and of the more important cities—that is, those not already investigated. Under this head the following investigators are working on the subjects assigned them for their particular States or cities.

Frederick A. Wood, Ph. D., Vermont.
Prof. C. M. Brough, University of Arkansas.
Prof. St. George L. Sioussat, University of the South.
Prof. E. L. Bogart, Princeton University.
Prof. W. A. Rawles, Indiana University.

Prof. W. A Burke, Albion College.
Prof. C. C. Plehn, University of California
Prof. N. A. Weston, University of Illinois.
Prof. J. A. Tillinghast, Converse College.
Prof Charles Lee Raper, University of North Carolina.
Mr. Laurence M. Larson, West Division High School.
Mr. R. V. Phelan, graduate student, University of Wisconsin.
Mr. W. O. Scroggs, graduate student, Harvard University.
Mr. J. W. Ellison, principal Wheat Ridge Schools, Colorado.
Prof. F. G. Young, University of Oregon.
Prof. James Boyle, University of North Dakota.
Mr. E. T. Miller, instructor in political science, University of Texas
Mr. W T. Nardin, graduate student, University of Missouri.
Mr. H. S. Hanna, graduate student, Johns Hopkins University.
Prof. Frank I. Herriott, Drake University.
Mr G. Gerald Bechtel, Butte High School.
Miss J. A. Flisch, under direction of Mr. U. B. Phillips, University of Wisconsin.
Mr. C C. Williamson, graduate student, University of Wisconsin.

Professor Gardner also has in preparation a card index of material bearing on the history of State and local finance. He is also collecting material for certain special studies, like the public revenue and expenditure—national, State, and local. In this he has the aid of William Jones, Ph. D., the work now being practically completed.

As announced in my report for last year, a committee was constituted to take in charge the preparation of a bibliography. This committee consisted of Messrs. North, Gardner, and Dewey, originally, and now of Messrs. Gardner and Dewey. Their first work is the indexing of State documents, governors' messages, and reports of executive officers and special committees for the purpose of ascertaining the references to financial matters. This work has been undertaken by Miss Adelaide R. Hasse, document cataloguer of the New York Public Library. This index will be available for all students engaged in the preparation of the "economic history," as well as the divisions of "money and banking and finance."

I feel sure that the undertaking authorized by the Carnegie Institution of Washington relative to an economic history of the United States will be, when completed, satisfactory. The project of the work has been received with enthusiasm by economists and historians, although some of the latter seem to feel that the work of the Department of Economics and Sociology should be devoted more specifically to the collection and publication of material rather than to the writing of a history.

The great associations—the American Economic Association and the American Historical Association—have evinced much interest in this work, as was shown by the fact that a joint committee (representing the two bodies) invited me to deliver an address before the

associations at Chicago in last December. This invitation I accepted, and in the course of my address I said :

It should be remembered that the really important work of the Department of Economics and Sociology of the Carnegie Institution is a great collection of materials which will be available for the historian if anyone desires to write a uniform history, for in order to be history the work will require a unity of thought which only single authorship can give * * * We realize fully that we are not going to cover the ground in a thoroughly exhaustive way, and that much must be left not only for the historian, but for the economist. We do intend to place the largest possible collection of materials in the hands of both, treating these materials we collect from the economic point of view—that is, the public welfare. This is our fundamental thesis ; this constitutes the difference between the historian as such and the economist, who uses history as an adjunct.

Smith, Mrs. Mary R., 86 South Park, San Francisco, California. Grant No. 194. *Study of the history of Chinese immigration to the Pacific Coast.* $1,000.

Abstract of Report.—During the past year the investigation into the history of the Chinese in the United States has reached the stage of organization of material. The first two months were spent in reading the reports and documents of the California legislature for fifty-five years ; the next four in reading the debates on the subject in the Congressional Record (1868–1904) and an immense number of committee reports; the correspondence of the State Department with China, etc. ; the next two in reading parliamentary papers and English books on the "coolie" trade and the emigration of the Chinese to western countries, which began in 1849. In this mass of hitherto almost unused material have been discovered facts of great importance in their bearing on the expediency of Chinese immigration, some of which have been overlooked heretofore and some of which have not been given proper weight.

The work has just begun of interviewing the Chinese themselves, to discover their motives in coming to this country, their attitude toward a republican form of government, whether they wish to return, and, in general, the degree to which they have become Americanized in habit and feeling. There is also a variety of material constantly coming to light concerning the effect of exclusion upon industrial conditions, upon the amount and supply of labor and capital, and the amount and kind of white immigration to the Pacific Coast.

ENGINEERING.

Durand, F. W., Leland Stanford Junior University, California· Grant No. 64. *Experiments on ship resistance and propulsion.* (For previous reports see Year Book No. 2, p. xxxii, and Year Book No. 3, p. 113.) $4,120.

Abstract of Report.—Professor Durand has been occupied with a general review of the results of his work and the preparation of his final report. He expects to present a partial or abstract report in the form of a paper for the Society of Naval Architects and Marine Engineers at the annual meeting in November, 1905. The final report will be reduced to form for publication a few months later.

Goss, W. F. M., Purdue University, Lafayette, Indiana. Grant No. 114. *Research on the determination of the value of high steam pressures in locomotive service.* (For first report see Year Book No. 3, p. 114.) $5,000.

Abstract of Report.—The original outline of this research provided for a series of tests upon a modern locomotive designed to be operated under very high steam pressures. Since the report of September, 1904, all portions of the work have proceeded in accordance with this outline, the tests contemplated having been run and good progress attained in analyzing results. The tests have been made in series, under pressures of 160, 180, 200, 220, and 240 pounds, respectively. The results of each series represent different conditions of speed and cut-off and serve as a complete definition of the performance of the engine under the pressure of the series in question. There have been made 71 complete boiler and engine tests and 27 tests for which indicator cards only were obtained. In the work of the year the experimental locomotive has been run the equivalent of 11,000 miles and has consumed 658 tons of coal. The whole investigation has been accomplished in coöperation with the authorities of Purdue University.

In addition to courtesies acknowledged in a previous report, material assistance has been rendered by the Lake Erie and Western Railway Company in transporting to Indianapolis and return, without charge, the experimental locomotive; also, by C. Jutte & Co. in furnishing coal, and by the American Locomotive Company.

A statement showing the progress made and presenting some of the facts developed appeared in the Railroad Gazette for June 9, 1905, under the title of "Locomotive performance under a steam pressure of 25c pounds." The final presentation of methods and results will soon be ready for publication.

GEOLOGY.

FUNDAMENTAL PROBLEMS OF GEOLOGY.

By T. C. Chamberlin,
University of Chicago.

I have the honor to submit herewith a report of progress on the work done under Grant No. 115 during the year ending September 30, 1905.

In my previous reports (Year Book No. 2, pp. 261–270, and No. 3, pp. 195–258) the antecedents of the present investigation were set forth, together with the progress made up to the close of September, 1904. To indicate the connection of the following studies, it may be recalled that investigations preceding the present series had given rise to grave doubts as to the validity of the accepted origin of the earth from a gaseous nebula, and hence had brought into question a long line of derived doctrines that enter profoundly into the current conceptions of the earth's history and of its dynamics. This had made a consideration of other possible origins imperative. In the report of last year the results of an inquiry into the possibilities of a meteoritic origin were set forth. The results were so adverse that this line of search did not seem to merit further pursuit. There was also set forth in that report the results of an effort to develop a working hypothesis of the origin of the earth from a spiral nebula having a planetesimal constitution. This necessarily involved a tentative hypothesis relative to the dynamic nature of spiral nebulæ, or at least of some of them, and a specific theory of their origin was presented. This had for its basal assumption the simple incident of one star, or other massive body, passing near another star affected by eruptive protuberances, and for its basal dynamics the inference that the eruptive protuberances would be intensified in mass and velocity by the tidal perturbations arising from the mutual attraction of the two bodies, and would hence be shot forth in both directions along the line of mutual attraction. In the specific case of the solar system it was postulated that, under the perturbing influence of a passing star, successive masses of matter might be ejected long distances from the sun, and that during their flight they would be so attracted by the passing star as to assume independent orbits and thus become secondaries to the sun and subject to aggregation into planets. (Year Book No. 3, pp. 217–219.)

* Grant No 115, $6,000. (For previous reports see Year Book No. 2, pp. 261–270, and Year Book No. 3, pp. 195–258).

From this conception a series of theoretical deductions were drawn forth relative to the mode of evolution of the solar system and the course of the earlier history of the earth, and these were tested by application to the actual facts so far as was then practicable. This hypothesis was worked out, essentially as set forth in my last report, in the absence of Dr. Moulton and without the advantage of free conference with him. It seemed desirable, therefore, that he should traverse independently the postulates and deductions from the view-point of the dynamics involved. This inquiry, as stated in the accompanying report, gave results altogether favorable to the hypothesis qualitatively, and this deepened the conviction that a more elaborate and laborious investigation on quantitative lines would be justified. Dr. Moulton has therefore undertaken, with the assistance of a computer, to trace out the approximate course that would be pursued by masses of matter ejected from the sun under the perturbing influence of a passing star, under different relations of mass, velocity, distance, eccentricity, etc , as set forth in the accompanying report. The results thus far reached indicate even greater potency in the postulated conjunction of agencies than had been assigned to it, both in the value of the perturbations of the ejected matter and in the range of results. It appears that even if the approach of a star of no greater magnitude than the sun were not nearer than the orbit of Jupiter and the solar ejections were limited to the mid-distances of the system, the ejected material (1) might in some cases be given orbits about the sun of varying dimensions and eccentricities; (2) might in other cases be captured by the passing star and take orbit of varying dimensions and eccentricities about it; (3) might in still others be given hyperbolic orbits and pass away from the control of either sun, and (4) might in still others return to the sun after pursuing variously perturbed courses, and by such return modify the rotation of the parent body—in other words, might give essentially the whole range of possible classes of results. It is therefore believed that out of the very great variety of possible cases which may arise from different combinations of mass, nearness of approach, eccentricity of orbit, velocity, and longitude of ejection, cases competent to produce a spiral nebula suited to evolution into a solar system may be found, and that consistent conditions of origin may be definitely postulated with no greater contingency in the basal assumption than the passage of a star in the vicinity of the sun.

My own work has consisted largely in the further application of the sequences of the planetesimal hypothesis to the various geological problems to which they are related. While an hypothesis of this kind must first of all meet dynamical and astronomical tests, is

must also meet the test of its working applicability to the complicated geological phenomena to which it is supposed to be antecedent, and the prime motive in this cosmological inquiry, so far as I am individually concerned, has lain in the imperative need for a more satisfactory working basis in geological dynamics, since the cosmological hypotheses previously entertained seemed to encounter serious, if not fatal, difficulties at many points of geological as well as astronomical application. In the endeavor to develop the applications of the new working hypothesis at as many vital points as possible my work has been quite distributive and is not easily reviewed in a brief report. Selected points may therefore best indicate the nature of the work and the character of the results, and of these I choose two.

I. Deformations of the Earth.

From the geological point of view the most radical departure of the planetesimal hypothesis from the gaseous and meteoritic hypotheses lies in the primitive structure of the earth. An origin from a gaseous nebula carries the corollary that the earth was originally a molten globe. The same appears to be true of the meteoritic hypothesis when the latter is assumed to have a quasi-gaseous constitution and to be aggregated directly by gravitation. Varieties of the meteoritic hypothesis may perhaps be postulated which would give rise to an earth built up by gradual accretion, essentially as under the planetesimal hypothesis, but after protracted effort I have been unable to give to such a postulate a plausible origin and a consistent working method. An earth built up by the gradual accretion of planetesimals may never have passed through the molten state, and hence its material may have preserved that distinctive heterogeneity which arose from the ingathering of the various kinds of material by individual accessions. The vulcanism of such a body must have pursued quite distinctive lines, as set forth in my last report (Year Book No. 3, pp. 238–244). The study of these methods has been carried to further details, but their general tenor is sufficiently indicated in the last report to serve the purpose of the present sketch.

The deformations in a body thus constituted must apparently depart even more radically from those of a body whose material has passed through the liquid state and has thus been subjected to such systematic arrangement of the material and distribution of the temperature as the liquid state must have permitted. The temperature of a body built up by the slow accession of material from without, whose heat of impact may have been largely lost by radiation from the surface in the course of the ingathering, must be assigned largely to compression under its growing gravity and to such molecular,

atomic, and subatomic activities, including the radioactive, as might arise under the conditions of the case. The presumption is therefore strong that the temperature would be very high in the central portions and would decline systematically toward the surface, and hence the secular effects of thermal changes would embrace not simply the loss of heat from the surface but the transference of heat from greater to less depths. The heterogeneous association of matter throughout the globe resulting from the postulated accretion must have given rise to great possibilities of recombination and rearrangement under heat and pressure in the interest of maximum density, and hence the hypothesis postulates such rearrangement and recombination as one of the potential factors in the deformation of the earth in the course of its history. As such rearrangement of material may have taken place at all depths, it is obvious that the problem of deformation under this hypothesis must take into consideration possible deformative agencies working throughout the entire globe. The redistribution of the heat by internal transference also involves this conception (Year Book No. 3, pp. 238–244). The deformative agencies, under the assumption of a molten globe, have, on the other hand, usually been regarded as essentially superficial, and hence the new system must be worked out on its own lines.

Reasons were set forth in my last report (Year Book No. 3, pp. 244–247) for believing that the water-covered areas of the growing earth, after it had acquired a hydrosphere, would develop a higher specific gravity than the land areas, due to differential weathering, and that these heavier water-covered segments would therefore take precedence in each great deformative movement in the interest of greater density. Not only would they take precedence in time, but in the amount of depression. If the deformations of the earth were limited merely to the protrusion of the continental platforms and to the depression of the oceanic basins, the dynamical explanation might rest with the differentiating effects incident to weathering on the land and hydrospheric protection under the water throughout the long process of growth; but the surface of the earth is still further differentiated by plateaus, anti-plateaus, and folded mountains, as as well as the minor phenomena of faulted blocks, warped surfaces, etc. Some of these clearly imply compressive lateral movements, while others as clearly imply crustal tension. The problem, therefore, embraces not only the massive shrinkage concerned in the formation of abysmal basins and continental platforms, but the accessory compressive actions involved in folded mountains and overthrust faults and the contrasted tensional actions implied by normal aults, gaping fissures, and other relaxative phenomena.

For the purposes of study, the earth may be conceived as formed of two sets of great sectors, or pyramids, having their bases at the surface and their apexes at the center of the earth. One set of these have as their bases the several ocean bottoms, and the other set the several continental platforms. If, as a first step of treatment, these be taken as units of action and it be recalled that they may be affected by shrinkage in all portions, but presumably in different degrees at different depths, certain hypothetical conceptions may be tested and either approved or rejected.

(1) If the sub-oceanic and continental sectors be supposed to have all shrunk in equable proportions in every part and simultaneously, the sectors would settle down each within its own limits and no unequal crowding would follow and hence no deformation. This conception is excluded by the facts of the case.

(2) If the outer parts of all the sectors shrank throughout proportionately more than the inner parts, each sector could not only have settled down within its own space, but could have suffered some tensional fissuring and faulting without involving lateral thrust or folding. This is also excluded by the facts of the case.

(3) If the sectors beneath the oceans simply contracted radially more than the continental sectors to the extent of about 3 miles, the existent continental reliefs might have been attained, but the phenomena of folding and overthrust would be left unexplained.

(4) If the sub-oceanic sectors sank first, as they should for the reasons previously given, and if by virtue of their superior gravity they wedged aside and squeezed up (relatively) the continental sectors between them, the continental surfaces would doubtless be warped and crumpled, and so the great reliefs, attended by some surface distortions, might be produced at the same time; but the question of the *proportions* between the degree of lateral thrust and of continental elevation at once arises. While no existing estimate of the total amount of lateral thrust expressed in folding and overthrust faults can be regarded as more than roughly approximate, the probable errors are not sufficiently great to vitiate the testing of this conception. If for this purpose we take the estimate of 100 miles shortening of the crust on a total circumference as the result of the folding since Cambrian times, it may be readily seen that if the continental sectors were squeezed proportionately throughout their mass so that their aggregate surface breadths were reduced by this amount, these sectors would be protruded several times as high as they actually are.

(5) If, however, the crowding of the master sectors were greater in the outer part than in the more interior portions, a greater amount of surface deformation in proportion to the continental protrusion

would result. To give such protrusions as constitute the great plateaus, the lateral compression of a segment having a depth proportionately related to the extent of the plateau would seem to furnish an appropriate agency, and hence the plateaus seem assignable to rather deep-seated lateral movements competent to cause a widespread upswelling of a large tract without excessive folding of its outer surface. In this and the preceding cases reduction of volume by compression, while recognized, is assumed to be a negligible factor.

(6) In the case of folded mountains, it soon becomes obvious by numerical trial that the lateral thrust of a crust of any considerable thickness, reduction of volume and downward deformation being neglected, gives an amount of protrusion quite out of proportion to the amount of folding and overthrust. For example, if a crust with a thickness of 20 miles were thrust laterally 40 miles—Lesley's estimate of the amount of the movement involved in the folding of the ridges in central Pennsylvania west of Harrisburg—and gave rise to a mountainous tract 60 miles wide, the average height would be 13 miles if the volume of the rock were essentially preserved by upfolding, an amount quite out of accord with the facts. An effort to bring the amount of lateral thrust and the amount of upward folding into harmony with the actual phenomena led to the very important conclusion that *the shell involved in the thrust and folding is a very superficial one.* It is obvious upon consideration that in an earth assumed to be solid throughout, whatever its origin, there should be a rather close correspondence between the amount of protuberance involved in the upfold and the amount of lateral thrust, for the very phenomenon of outward folding implies that this is the direction of least resistance for the operating stresses. Downward protrusion can scarcely be assumed to be an important factor in this case—at least a downward protrusion that does not by displacement at the same time contribute to outward protrusion. While compression doubtless results in some increase in the average density of the rocks affected, neither theoretical calculations nor pendulum observations warrant the belief that this constitutes an appreciable factor, and hence, as indicated, the outward protrusion of the folded tract and the amount of lateral thrust should be elements which mathematically combined indicate the depth of the thrust shell. For example, if the thrust be 40 miles, the folded tract be 60 miles, the highest fold be 5 miles, and the average elevation of the folded tract be 2.5 miles previous to denudation, the depth of the thrust shell must be 3.75 miles, neglecting changes of density, downthrust, etc. If the average elevation of the folded surface were 3 miles, the shell must have been 4.5 miles thick. Now, these are the numerical factors involved in the

folding of the Appalachian tract of Pennsylvania west of Harrisburg, according to Lesley's estimate.* The application of this method to other mountain ranges for which approximate estimates of the crustal shortening and the height of the folded tract are at command gives results of a similar order of magnitude. Recognizing the imperfections of such estimates, it may be assumed for the purposes of further consideration that the superficial shell involved in folding is of the order of 3 to 5 miles in thickness rather than of dimensions of a markedly higher order, such as the supposed thickness of the crust of the earth overlying a molten interior or a mobile substratum The considerations that lead to this conclusion are applicable to an earth of any internal constitution unless it be supposed that the folding involves inward flexure of such an order as to produce a widespread displacement instead of contributing to a definite external protrusion.

It is obvious from this and from the further considerations that will presently be offered that the determination of the amount of crustal shortening involved in mountain folding and faulting, together with the resulting external protrusion, are elements of importance, and that more careful determinations are eminently desirable. This has led to a consideration of methods for such determinations, and some devices not known to be in use have been developed and put to preliminary tests. It is thought desirable, however, to carry these further before committing them to print.

The deduction that the shell involved in mountain folding is so limited in depth seems to carry the necessary corollary of a shear zone between it and the great body of the earth. This zone must lie within the horizon of solid rock, for under no tenable hypothesis can a molten stratum be assigned to so shallow a depth. This shear zone appears to lie at or above the junction between the zone of fracture and the zone of flowage deduced by Van Hise and Hoskins from the relations of vertical pressure to the crushing strength of rock, which is placed at a depth of about 10,000 meters. If we seek for a cause for shearing at this horizon rather than a higher or lower one, it is probably to be found in the relationship between the weight of the overlying rock and the shear resistance of the rock at the given horizon, very much as the limit between fracture and flowage deformation is found in the ratio between the weight of the overlying rock and the crushing strength of the rock. The shearing strength of rocks representative of the horizons involved is scarcely known at all experimentally, but it may theoretically be assumed with confidence to be somewhat less than the crushing strength, and hence the

* 2d Geol. Sur. Penn., Pt. X, p. xxi, 1885; also Summary, Final Rep., p. 206, 1903.

deduction from the present imperfect data which places the shearing zone from 3 to 5 miles beneath the surface is in fair accord with the deduction of Hoskins, which places the limit of resistance to crushing at about 6 miles.

It is inferred from the nature of the case that the shear horizon is not a definite plane, but rather a zone of some depth which is affected by more or less distributive shear, accompanied by drag and foliation, the phenomena being analogous to distributive faulting and attendant drag and foliation. The shear zone is thus conceived to involve the development of foliation and schistosity through a considerable depth. Ideally each individual foliation plane is assumed to cross the shear zone by a double curve whose middle portion is nearly parallel to the earth's surface and coincident with the main plane of shear. Generalized, this grows into the conception of a nearly or quite universal zone of foliation or schistosity enveloping the body of the earth beneath the superficial shell, for though the shearing at any specific time would involve an appreciable motion in only a portion of the shell, the shearings of different times in geological history taking place under different conditions and from different centers of movement are assumed to have given the shear zone a nearly or quite universal extent.

This conception is enforced by a study of the distribution of the folded tracts of any great period of deformation. These do not seem to be distributed throughout the earth generally, or at frequent intervals, which would involve many small foldings and limited shear, but rather to be concentrated in a few great tracts which involve a common shear movement for large sections of the shell. This is confirmed by the great extent of the shear that is implied by the amount of the folding. If the conception of concentration from wide areas be not entertained, the necessary alternative seems to be the assumption of a very large total shrinkage and of more tracts of folding than observation warrants. Under this alternative also the total amount of deformation becomes embarrassingly large from the dynamic point of view.

The conception of a shear zone acting as a zone of accommodation between the superficial shell and the great body of the earth leads on to two suggestive geological applications:

(1) In the nature of the case, volcanic extrusions in passing from beneath the shear zone to the surface may reasonably be supposed to follow preferentially the flexed foliation planes of the shear zone as the lines of least resistance. As this is a zone of cool rocks, the lavas must be presumed to suffer more or less stiffening and lodgment within it by progressive cooling. This lodgment should normally

take the form of sheets or lenses interwedged among the foliations, particularly those that were more nearly horizontal. These intrusions may be assumed to have tended to take two forms—the first distributive, consisting of an intimate intrusion of thin sheets between the foliæ of the sheared zone, and the other more concentrative, in the form of large lenses, with, of course, irregularities of all sorts.

(2) It is conceived that the shear zone of the earliest ages has been exposed by denudation where the body of the earth was most protuberant, and that this exposed portion constitutes at least a part of the great foliated and schistose area of the Archean, with its abounding and extensive batholiths. Thus the extraordinary prevalence of foliation and schistosity, with interleaved igneous layers and embedded batholiths, finds a seemingly consistent explanation. The shearing itself may tax our dynamical conceptions, but if it is required by the phenomena of folding there is some dynamic gain in finding in it also a solution of the rather grave problems presented by the prevalent foliation and the prodigious batholiths of the Archean. The formation of the foliation by the mashing of a relatively thick crust and the introduction of the batholiths by the massive vertical intrusion of great igneous bodies make very severe demands on dynamical energies.

By the foregoing combination of deep-seated and superficial agencies the different grades of deformations of the primary order are thought to be consistently accounted for, both in the matter of providing for an adequate amount of shrinkage and in its proportional application to the different classes of deformations. More specifically, it is thought that in the rearrangement of heterogeneous material in the body of the earth, combined with internal transfers of heat as well as external loss, together with volcanic extrusions, adequate possibilities of shrinkage are postulated, even when it is recognized that this shrinkage must have been large. A similar adequacy can not apparently be assumed with equal confidence when external loss of heat, vulcanism, and other superficial changes, of whatever kind, are alone appealed to. In the differential shrinkage of the great sectors under the modifying action of the atmosphere and hydrosphere during growth, an apparently competent agency for the development of continental platforms and oceanic basins is provided. In the differential shrinkage of deep segments of the outer portion of the earth is postulated a seemingly adequate and appropriate agency for the formation of plateau-like protuberances and the great differential swells of the continental protuberances, while in the shear of a very superficial shell whose rigidity is too high relative to its weighting to be plastically deformed is found the agency involved in the folding of mountain ranges and the phenomena of overthrust faults.

All the foregoing agencies involve thrust stresses in the main and are only competent to explain thrust or compressive phenomena. It remains to find an adequate agency for the production of tensional faulting and other relaxative phenomena. These are much more prevalent at the surface of the lithosphere than are compressional phenomena, though their aggregate value is apparently less dynamically. Tensional faulting is the "normal" form, and the sum total of gaping fissures filled and unfilled is large. These tensional faults are assigned in the main to secondary action growing out of the strains developed by the protrusions incident to the primary actions already described. The continental platforms rise from 2 to 8 miles above the abysmal bottom of the ocean, with an average of perhaps 3 miles. Three miles of rock exerts a pressure of 16,000 to 30,000 pounds to the square inch, according to the class of rock. The continental platforms may roundly be assigned a pressure of 20,000 pounds to the square inch on their bases, and hence a tendency to creep laterally, much as does a glacier. This is opposed by perhaps 5,000 pounds pressure per square inch arising from oceanic waters. The difference between the two pressures leaves a working margin that approximates to the shearing strength of average rock, and hence it is conceived that the continental platforms, yielding to this persistent pressure, creep laterally in a slow, glacier-like way. The previous establishment of a zone of shearing with the development of shear planes is presumed to facilitate this lateral movement, and hence arises the conception that a relaxative movement follows the primary movement, resulting in the slow spreading of the continent with the development of fissuring and normal faulting. The origin of earthquake tremors as an incident of this process is an obvious suggestion.

The conception of a comparatively thin superficial shell subjected to compressive thrust during times of body shrinkage and general deformation, followed by slow and persistent relaxative movement of the opposite phase in the intervals between general deformations, furnishes appropriate grounds for elucidating many of those very gentle changes in the relations of land and water which characterize the great periods of quiescence of the earth's history, without destroying the validity of the general conception of quiescence. It also furnishes an alternative explanation of the remarkable behavior of the continental borders, by virtue of which the exogenous growth of the continents has been persistently mutilated and river valleys and other channels submerged to extraordinary depths. These latter have usually been assigned to vertical oscillations of the continental masses; but, besides making grave demands on dynamic possibilities and introducing difficulties in disposing of the displaced oceanic

waters, this is not well supported by physiographic and faunal evidences. The lateral shear of a relatively thin shell, whose thickness is a function of rock pressure and rigidity and which hence has an undulatory base rudely concentric with the surface of the lithosphere, provides a mode of emergence and submergence by oblique movement of the shell, without involving much massive movement of the continents beyond the shrinkage concerned in general deformation. This explanation compasses at once the rejuvenation of the streams back from the coasts, so markedly expressed in falls and rapids and the submerged valleys off the coast, which seem to be coördinate phenomena and common to all coast tracts.

II. Climatic Oscillations.

Another chief line of study lay in the endeavor to work out, as a sequence of a planetesimal origin of the earth, a working system of hypotheses relative to atmospheric states and their expression in the climates of geological history. In my previous report the origin and general history of the atmosphere, involving a postulated system of secular supply and depletion, were outlined (Year Book No. 3, pp. 233-238). The supreme test of all atmospheric and climatic doctrines seems to center in the remarkable phenomena of the Permian period, for at or about that time the earth was affected by glaciation in India reaching southward slightly across the Tropic of Cancer, in Australia reaching northward to the Tropic of Capricorn, and in South Africa covering a large area in Cape Colony, Natal, Zululand, the Orange State, and Transvaal, while at or about the same time prevailing aridity is indicated by salt and gypsum deposits and associated Red Beds distributed through extraordinary ranges of latitude and longitude. Apparently at no other period of geological history were the phenomena of glaciation and aridity so extraordinarily manifested. At the same time it is to be recognized that substantial evidences of glaciation are found as far back as the early Cambrian or pre-Cambrian times (Norway, China, Year Book No. 3, p. 282, Willis), and evidences of very extensive aridity are exhibited in Silurian and earlier periods, while both these phenomena have had marked expressions in more recent geological times. On the other hand, very mild climates in polar latitudes are evidenced by marine and land life at several periods in the course of geological history falling between the extraordinary expressions of glaciation. The climatic problem, therefore, instead of shaping itself, as we once supposed, as a question of decadence from an extremely hot, moist, uniform state in the earlier history, to a state of relative aridity and glaciation

in its later stages, is found, by progressive investigation, to take the form of oscillations between extraordinary polar mildness and uniformity, on the one hand, and remarkable stages of glaciation and aridity in low latitudes on the other. The solution rests in the discovery of conditions competent to preserve subtropical life in the polar latitudes through the six months, polar night on the one hand, and the production of extensive sheets of ice on relatively low tracts on the borders of the torrid zone on the other.

In lieu of the more familiar hypothesis of a primitive atmosphere of vast extent and hot, vaporous nature, carrying most of the constituents that have since been consumed in the carbonation and oxidation of the outer part of the lithosphere, the planetesimal theory substitutes an atmosphere of essentially the present magnitude gathered gradually during the growth of the earth and unaffected by the extraordinary conditions attending a molten sphere. By hypothesis the atmosphere was maintained by a system of feeding from within the earth and from cosmical sources, and suffered loss from its contact with the lithosphere, chiefly by carbonation and oxidation. Thus its fluctuations in mass and constitution were dependent on the balance between supply and consumption. In this it furnishes the basal conditions under which coördinate agencies are thought to have produced the oscillations between climatic mildness and uniformity, on the one hand and extraordinary diversity and severity, on the other. The atmospheric supplies are presumed to have varied essentially with the volcanic activity of the earth, modified possibly by variations in the cosmic supplies, but of these we have no knowledge and little basis for intelligent conjecture. The consumption of the more active constituents is assumed to have varied with the amount of effective contact between the atmosphere and the lithosphere, which in turn varied chiefly as the extent of the land and its degree of protrusion above the sea-level changed. In a general way it seems probable that volcanic activity increased with the deformations which augmented the protrusion of the land, and hence that, in a general way, increase of supply was correlated with increase of consumption, and so the atmosphere was protected against excessive variations and the continuity of life was preserved. But the geological record forces the recognition of very marked oscillations of climate, as stated, and hence the inference that the correlation of atmospheric supply and consumption was not perfect and that oscillations of composition and mass marked the earlier as well as the later stages of the atmospheric history. This is based on the assumption that the atmosphere exercises a controlling influence over climate, and that, though not the only factor, it supplies the basal conditions under which other factors operate.

Under the general conditions of depletion and supply dependent on deformation and vulcanism, the earth maintains a system of storage and free delivery which effectually abets these primal agencies in the maintenance of a serviceable working mean, viewed from the standpoint of life, while it incidentally develops oscillations of its own. This storage agency is found in the ocean, and a special feature of the work of the year has consisted of a study of the function of the ocean as an atmospheric reservoir and regulator, particularly its action in the absorption and release of carbon dioxide. Besides the climatic relations of this study, it considered the sources of such large supplies of carbon dioxide as went to form the limestones and other carbonates, together with the coals and other carbonaceous deposits, and the consistency of such supplies with an atmosphere not too highly carbonated to permit a continuance of active life on land and sea. The testimony of the life record seems to indicate that the variation of carbon dioxide in the atmosphere, while it may have been considerable, was never very profoundly greater nor very profoundly less than that of the present time, if by this expression is understood a supply never many times greater nor many times less than the existing quantity. The subject in its totality is too complex for fair presentation here and only a few salient features will be touched.

The function of the ocean as a reservoir of atmospheric materials has been for some time recognized by special students of the subject, but its working methods have not been elaborated and some serious misapprehensions of its effects have been entertained. The ocean carries carbon dioxide not only by absorption as carbonic acid, but also in combination as the acid element of carbonates and bicarbonates, from all of which, under certain conditions, it may be separated and given forth into the atmosphere. While held in the combined state it is essentially innocuous to animal life. The ocean may thus have held within itself, in a condition harmless to life, 60 or 80, or possibly 100, times the amount of carbon dioxide now contained in the atmosphere; while, on the other hand, it may have been so far depleted by the removal of its carbonates as to contain but a small multiple of the atmospheric content. My studies lead to the belief that this variation could have taken place without necessarily involving corresponding fluctuations in the atmospheric content, for while a certain equilibrium must be assumed to have existed between the carbon dioxide of the atmosphere and that of the ocean, the basis of equilibrium was susceptible of very wide changes by the increase or diminution of the carbonates of the ocean.

In this way it is possible that at times when the atmosphere was relatively rich in carbon dioxide the ocean was relatively poor in the same constituent. The supply of carbonates, which was a controlling factor, was measurably dependent upon the ratio between the exposure of the land surface to atmospheric contact on the one hand and the conditions for the extraction of the carbonates furnished particularly by the epicontinental seas on the other. The variation in these relations is believed to have at times favored the enrichment of the ocean in carbonates, and at other times its depletion, and hence to have changed the basis of equilibrium with the atmosphere.

In the study of the interchange between the carbon dioxide of the ocean and of the atmosphere, it appeared that direct diffusion was but feebly competent, because of its slowness of action, and, further, that the mechanical intermixture of atmosphere and ocean through wave and current action was too superficial to more than moderately supplement the feebleness of diffusion. The familiar ocean currents appear to be essentially superficial, and probably do not greatly assist in the interchange between the carbon dioxide of the atmosphere and that of the great abysmal body of the ocean. It is clear, however, that there is now a profound circulation of a different and much slower type, which affects this abysmal body and in the course of a long period exposes it at the surface. This profound circulation at present is actuated by the low temperature and the concentration of salinity arising from the freezing of the surface water in the polar regions. To this profound circulation must apparently be assigned the task of changing the state of carbonation of the great body of the oceanic waters so far as it is dependent on interchange with the atmosphere. When the deep-sea circulation has its present phase, *i. e.*, when the waters descend in the polar regions, move thence toward the Equator, rise in the low latitudes, and thence return superficially to the polar regions, it tends to carbonate the deep waters of the ocean to a degree higher than that of the average state of equilibrium between the ocean and the atmosphere, because the coefficient of absorption of carbon dioxide for the low temperatures of the polar regions is roundly double that of waters at the equatorial temperatures and much higher than that at average temperatures. The result is that the deeper body of the ocean is cold and somewhat supercarbonated relatively to the average atmospheric state. This appears to find expression in the solution of carbonates which is now prevalent in the depths of the sea. This tendency to supercarbonation is intensified by the freezing of the surface waters in the polar

regions by virtue of which the carbon dioxide of the frozen layer as well as the salts is forced out into the layer beneath and supercarbonates it, while the increased salinity aids in its descent and promotes the profound circulation.

In attempting to estimate the efficiency of the polar agencies in promoting this deep circulation and thus to reach some estimate of its period, the fact was disclosed that the evaporation of the low latitude belts of relatively dry descending atmosphere and of trade winds caused an increase of specific gravity through increased salinity somewhat closely comparable to the increased density effected in the polar regions by low temperature and freezing. Out of this arose the suggestion that in those periods in which low temperatures and freezing in the high latitudes were absent or limited, as indicated by the faunal and floral record, their efficiency in increasing the density of the sea-water might have been overbalanced by the increase of density due to evaporation in the low latitudes, and *that the deep-sea circulation of these periods may have been the reverse of that of the cold periods, being actuated by evaporation in the low latitudes.* The data for developing this suggestion into a firm conclusion are not at command and, with the degree of study thus far given it, it can only be regarded as a suggestion whose importance depends on its justification. It is at once evident that if such deep-seated circulation from the Equator to the poles were actually realized, the warmth of the polar regions in such periods would cease to seem extraordinary, because the waters descending in the low latitudes with a subtropical temperature would give to the whole abysmal mass of the ocean a corresponding temperature, and would rise in the polar regions with little or no loss of heat and give forth warm vapors which would enshroud the polar regions during the protracted night and protect them from effective low temperatures, while during the protracted day the temperatures would be hospitable to subtropical life.

This suggestion also furnishes a possible elucidation of the periodicity of the glacial and interglacial epochs, for while a reversal of the circulation can scarcely be postulated during the prevalence of the general conditions which favored glaciation, a profound change in the carbonation of the sea-waters and a correlated change in the carbonation of the atmosphere is readily deducible from the deep-sea circulation. This, however, is coördinated with other influential conditions and with other assumptions which render the case too complex for statement here. This sketch is merely intended to indicate the lines of study and something of their applicability.

REPORT OF F. R. MOULTON,

University of Chicago.

During the past year I have been engaged in two general lines of inquiry. The first has been to find out whether our solar system could have developed out of a "planetesimal nebula" having a few nuclei of considerable dimensions. The test has been made with respect to all the more important features of the system, such as the rotation and equatorial acceleration of the sun, the direction of revolution of the planets and the small relative inclinations of their orbits, the small eccentricities of the planetary orbits, the directions of rotation of the planets, the origin of satellites and their directions of revolution, the eccentricities of the orbits of the satellites, and the orbits of the asteroids. Although several of these questions had been considered by Professor Chamberlin, it seemed advisable to go more fully into the dynamics of the whole theory in order to be perfectly sure that it would justify the undertaking of the extensive computations which we are now carrying out. The results obtained have been in all cases qualitatively favorable to the theory. In order to test the theory quantitatively it seems to be necessary to make some assumptions respecting the eccentricities of the orbits of the original nuclei and of the great number of small bodies which they have swept up. The necessity of making these assumptions has driven me to the second line of inquiry. The details of the results obtained in the first line of inquiry may, I think, be more profitably withheld until they shall have had complete quantitative application.

The second line of inquiry is respecting the possibility of a planetesimal nebula originating from the matter ejected by one sun while another sun is passing near it. A rough preliminary examination, something like the one made by Professor Chamberlin, showed that there is a strong probability that planetesimal nebulas may originate in this way. While it is a simple matter to find the character of the disturbing forces for any relative positions of the two suns and the ejected material, it is a very laborious task to compute the continued effects of these forces, for they are not only large, but they vary in a most complicated manner. In some cases it has been necessary to follow the perturbations for more than twenty years.

The problem of three bodies of the type considered here is not susceptible of general treatment by the mathematical processes now in use, and it has been necessary to go to the examination of special typical cases by numerical processes. In this work I have had the very efficient assistance of Mr. Elton James Moulton, who has car-

ried out the computations intrusted to him with accuracy and enthusiasm. The number of cases to be examined in order to get an adequate understanding of the subject is very great, because of the variety of circumstances which may modify the motion of the ejected material. They are (1) the nearness of approach of the disturbing sun, (2) the mass of the disturbing sun, (3) the eccentricity of the orbit of the disturbing sun, (4) the longitude of the disturbing sun from the perihelion at the time of the ejection of matter, and (5) the velocity of ejection. In any combination of these circumstances there are two cases, for the matter may be ejected either toward or from the disturbing sun.

If it is assumed that three values for each one of the factors which modify the orbits of the ejected material will give a sufficiently accurate idea of what may happen, it is found that there are altogether 486 separate orbits to be computed. This gives some idea of the magnitude of the problem we have undertaken. For most of the factors three values are by no means an excessive number. For example, it will in all probability be necessary to consider the differences in the orbits when the material is ejected some time before the disturbing sun reaches perihelion, while it is at perihelion, and some time after it reaches perihelion. However, it is not likely that it will be necessary to examine the whole 486 orbits, for we shall presently have enough data so that our conjectures will become more valuable and certain.

So far we have computed 9 orbits. The results are of the most varied and surprising character. In 4 of these 9 cases the ejected materials were left moving in elliptic orbits, in 2 of them they were sent away from both suns in hyperbolic orbits, in 2 of them they were captured by the disturbing sun, and in one of them the ejected materials fell back into the sun after making a great loop. If we add to this list the obvious case where the material is ejected with a small velocity and falls back into the sun without being much perturbed, we shall have nearly every imaginable result.

The velocities of ejection were in all cases moderate, never being enough to carry the matter, if it were undisturbed, much beyond the orbit of Saturn. The fact that under these circumstances matter can be driven beyond the gravitative controls of both suns is very surprising, and, if I am not mistaken, an important result. It shows the disintegrating effects of gravitational forces, whereas we have heretofore regarded gravitation as uniformly tending toward concentration. Although we did not have this question of wide dispersion in mind in taking up these computations, it may be that in

carrying them out we shall obtain a good idea of the importance of these processes in cosmical evolution.

In all the orbits so far treated the disturbing sun, which we shall call S′, was supposed to have the same mass as our sun. It was supposed that it moved around our sun, S, in a parabolic orbit. In the first case it was supposed that the perihelion distance of S′ was five astronomical units, or nearly the distance of Jupiter. The ejection was supposed to have taken place when S′ lacked 90° of being at the perihelion of its orbit. The ejection was supposed to have been both toward and from S′ with velocities sufficient to carry the material, if it were undisturbed by S′, out to 10 astronomical units.

Let us consider first the material ejected toward S′. Its deviation from a straight line was slight until its distance was about six astronomical units. At this time it was moving in an hyperbolic orbit with respect to S. Then its direction of motion was rapidly changed by the perturbations of S′, and the eccentricity of its orbit rapidly decreased. By the time S′ had reached its perihelion the ejected material had moved through a heliocentric angle of about 40°, the eccentricity of its orbit had become small, and it was near the perihelion of its orbit. A little later its orbit became exactly circular. Then it became again elliptic with the ejected material near the aphelion; that is, the aphelion and perihelion had changed ends by the orbit passing through the circular form. The perturbations turned the orbit in more and more toward the sun until the eccentricity had increased to 0.97 and the perihelion distance had shrunk to 6 500,000 miles. At this point the effect of S′ became negligibly small. The large eccentricity was produced by an excess of perturbation by S′. It would have been smaller if the mass of S′ had been taken less, if S′ had been moving in a hyperbolic orbit, or if the ejection had occurred when S′ was nearer its perihelion.

The particle which was ejected in the direction opposite to S′ went in nearly a straight line until it had receded eight astronomical units. All of this time S′ was tending to increase its velocity. Then it began to curve off in the direction in which S′ was traveling around S, but S′ continued to accelerate its speed. The result of this acceleration was that the orbit became hyperbolic with an eccentricity at one time probably exceeding 2.0; but when S′ got about 115° beyond the perihelion its effect on the eccentricity was reversed and it steadily decreased until it was 0.98. While the perturbations of S′ were still sensible, it was not thought anything of value would be learned by pursuing this case further. The major axis was over 1,500 astronomical units and the perihelion distance was about 20. The major

axis and eccentricity would both have become smaller if the computations had been carried further.

The next cases considered were the same, except that the velocities of ejection were taken less. On the side toward S′ the velocity was taken sufficient to cause the matter to recede, if undisturbed, to the distance of eight astronomical units. The curve described was much like the one found in the other case, except that the perturbations

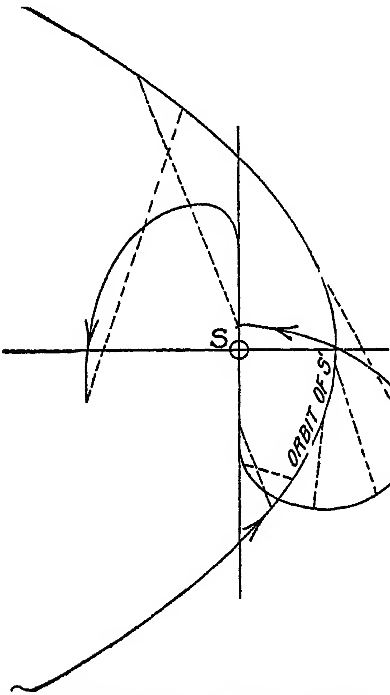

FIG. 3.—Diagrammatic illustration of Case 2.

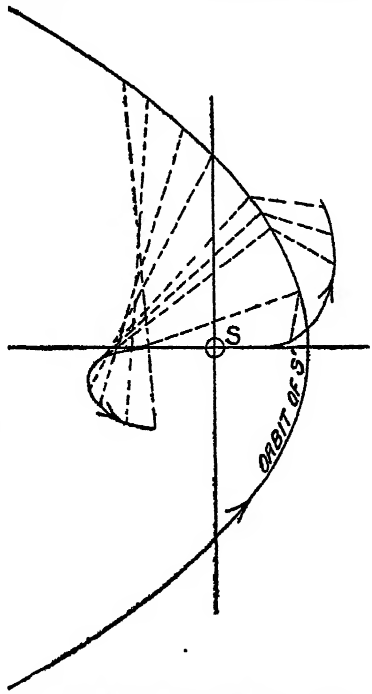

FIG. 4.—Diagrammatic illustration of Case 5.

were always somewhat less. When S′ had receded so that its influence had become negligible, the matter was found to be moving in an orbit whose eccentricity was 0.89 and whose perihelion distance was 55,000,000 miles.

The matter which was ejected in the direction opposite to S′ was given a velocity sufficient to cause it to recede, if undisturbed, to the distance 6. It made a much more rapid curve than in the first case, and was left moving in a hyperbolic orbit. These orbits are shown in fig. 3.

In the next computation the perihelion distance of S′ was supposed to be half as great as the distance from the earth to the sun. The ejection took place when S′ was 90° before its perihelion, and the

initial velocities were sufficient to carry the materials, if undisturbed, to the distance unity. The matter ejected toward S′ was left moving in an ellipse whose eccentricity was 0.98 and whose perihelion distance was about equal to the radius of the sun. That which was ejected in the direction opposite to S′ was left moving in an hyperbola whose eccentricity was about 1.5.

The next case was the same, except that the material was ejected toward S′ with a velocity sufficient to make it recede, if undisturbed, only to the distance 0.5. In this case the material was captured by S′, and when it had receded so that the disturbance of S became small its eccentricity with respect to S′ was 0.64 and its periastron distance 26,000,000 miles.

The next case treated was different, in that the matter was supposed to be ejected when S′ was at its perihelion at a distance 5 from S. The velocities of ejection were such that the material would have gone out to the distance 5 if it had not been disturbed. That which started out toward S′ was captured. When this fact was assured it was not followed farther, and the eccentricity of its orbit was not computed. The matter which was ejected in the direction opposite to S′ was left moving in an ellipse whose eccentricity was 0.53, whose major semi-axis was 4.5. and whose perihelion distance was 2.09. The orbits are illustrated in fig. 4.

Up to the present orbits have not been found having quite so small eccentricities as we should expect those bodies had which have united to form our planets. But the work has gone so far that it has shown us that they almost certainly exist. The very variety of the possibilities disclosed will assist us, if this theory of the origin of our system is true, in finding more exactly the antecedents of the planets. The work at present seems to me to be very promising of fruitful results.

It does not seem advisable now to enter into the details of explaining the methods of computing we have used. They have varied with the character of the motion and the magnitude of the disturbing forces. Experience is suggesting modifications, and there is much yet to be hoped for in the line of brevity. We shall also have to examine more carefully the effects of the approximations made than we have done so far.

STUDY OF THE BASIN RANGE STRUCTURE AND GLAUCOPHANE AND ASSOCIATED SCHISTS OF CALIFORNIA AND OREGON.

Louderback, George D., Nevada State University, Reno, Nevada. Grant No. 167. (Continuation of Grant No. 66.) $1,300.

The first part of this study had been completed and the work during the past year was devoted to the schists. The questions involved included (*a*) their distribution areally and geographically; (*b*) their exact geological relations; (*c*) their petrographical characters and description; (*d*) the materials from which they were formed; (*e*) the active agent or agents giving rise to their formation; (*f*) the process by which the metamorphism was brought about.

Among the chief difficulties encountered are the sporadic occurrence and the lack of contacts—in fact, the general lack of positive evidence. This has led to the most diverse views by different observers, and after studying one or two localities carefully it was seen that the utmost care in some areas might yield meager results, and that the chance occurrence of a good contact or of a definite transition form might play an important part in solving the question of origin.

Furthermore, it was found that a number of subsidiary questions should very desirably be answered before the main question was solved. Among these were, the age of the sedimentary rocks with which the schists are associated, and whether they are associated with rocks of different ages and lithological characters in California and Oregon, as appears from the literature. The study indicated that the Mesozoic of Oregon was not correctly classified and presented in the atlas sheets now published, and that the subdivision of the rocks of this era and the associations of the schists are the same as in central California.

As for the main question, the schists at several localities in southern Oregon and in central California have been studied and a large number of specimens gathered.

Dr. Louderback expects to continue his work and when finished to present his results for publication.

GEOLOGICAL EXPLORATION IN EASTERN CHINA.

Willis, Bailey, U. S. Geological Survey, Washington, D. C. First supplement to Grant No. 116. (For previous reports see Year Book No. 2, p. xxxv, and Year Book No 3, p. 118.) $7,500.

The field work of 1903 and 1904 resulted in notes and maps embodying materials for publication concerning which recommendations were made in the report of October, 1904, to the effect that there should be published:

Report A.—Detailed geology; a statement of observed facts, arranged geographically by provinces and districts, comprising an atlas of forty topographic and geological maps, and a quarto volume of about 300 pages, with maps and illustrations.

Report B.—A volume on paleontology of the Cambrian, Ordovician, and Carboniferous, prepared by specialists, and also a brochure on zoölogy.

Report C.—Studies in comparative geology of North America, Asia, and Europe; a discussion of continental histories and mountain growth, to form a separate contribution and publication.

Regarding the state of progress on Reports A and B, it is estimated that both the volumes will be ready to submit for publication not later than February 1, 1906. The topographic maps for the atlas are engraved and the geologic maps are being drawn. A box of specimens containing some fossils and the principal collection of pre-Cambrian rocks was lost in transit and was not recovered till May, 1905. It was then shipped from Tientsin, but did not come to hand till in November. The rocks are being studied by Mr. Blackwelder, a matter of two months' work. The conclusions we had reached may be modified by the additional evidence. Accordingly it is proposed to complete the manuscript for the volume, but to hold it till the additional specimens shall have been studied, so that the final results may be incorporated.

Report C was contemplated in the original purpose of the grant of 1903, for studies in comparative geology of North America and Asia, and its scope was extended by the authority given in the supplementary grant of 1904, to pursue parallel investigations in Europe. The work done during Mr. Willis's stay abroad, from February to June, inclusive, is accounted for below. As a principal result of the journeys of the past two years, he is in possession of data relating to the geology of Asia and Europe which may be discussed with reference to similar facts of the geology of America. The broad problems to which this discussion will be a contribution may be

stated as those of continental histories and mountain growth. Continental evolution will be treated from the point of view of continuous geographic changes, so far as the assembled data permit, and the three continents will be compared. Mountain growth will be considered as a study of altitudes and depressions as phenomena of earth warping, in contrast to mountain building, which is the study of the internal structures. The latter represents an earlier view of the origin of mountains, still dominant in Europe, but being superseded in America by the former, which is based on the modern science of physiography.

The preparation of this Report C involves reading to assemble facts beyond the range of observation, particularly with reference to Europe and Asia. It is thus a continued study, to which more or less time might be given, but which can be adequately executed within the year, to October 1, 1906. That being done, the purpose of the original and supplementary grants for research in eastern Asia will have been accomplished and the work be brought to a close.

During five months spent abroad, February to June, inclusive, 1905, leading scientists of Europe were consulted on questions of Asiatic and European geology, and a mutual understanding of views was established with a satisfactory degree of agreement. It is particularly gratifying that opportunity was afforded to lay the results of research in Asia before Baron von Richthofen, the great explorer of China, who has since died. In relation to a particular problem of continental geology—the study of the mountains of Europe in comparison with those of North America and Asia—journeys were made throughout central Europe, across the Balkan peninsula to Constantinople, and into Asia Minor. In general two types of mountains were seen: (*a*) The mountains of central Germany and northern Austria, which were folded at the close of the Paleozoic, were eroded to a peneplain during the Cretaceous, and have since passed through a complex history of warping and erosion; and (*b*) mountains of the Karpathian type, which were folded during the Tertiary, were subsequently eroded to a surface of mature topography, still retaining marked relief, and have since been strongly warped, in some cases before the close of the Tertiary, in others during Quaternary time. Mountains of the class (*a*) are similar in history to the Appalachians. The Karpathian type (*b*) has no analogues in America so far as known, but is probably closely related to the Himalayas. The interpretation of the mountains of Europe is to some extent novel and offers a new conception of the physiographic history.

STUDIES IN EUROPE.*

By Bailey Willis.

Object of the journey.—During 1903 and 1904 I had been engaged, under the auspices of the Carnegie Institution of Washington, in geologic research in eastern Asia, and had gathered data which supplement previous knowledge of the continent; to some extent they also qualify both it and the theoretical views published by European geologists. It was desirable to lay the new facts and novel interpretations before the leading European students of Asia, in personal conference, and this was one principal object of the journey.

A second purpose was to extend to Europe studies in comparative geology of continents, already begun for North America and Asia. The particular subject of comparison is that of the age of mountains and the relation generally thought to exist between the internal structure of ranges and their present elevation. This subject is one in regard to which opinions are changing in Europe as well as in America, but more slowly abroad, and I wished to see whether there were other types of mountains there than are found in the United States and China.

To these ends the journey was planned to visit certain scientists for conference and certain mountain ranges for investigation.

Itinerary.—Sailing from New York February 4 and going via Naples, I reached Berlin March 5 and remained till the end of the month. Vienna was my headquarters during the first half of April. Leaving there April 16, I returned May 15, after having scanned the phenomena of the Croatian coast, of the northern Apennines, and of the Basse Alps. The latter part of May was spent at Vienna and in an excursion to the Bohemian highlands. May 31 I left for Belgrade, the Balkan Mountains and Danube Canyon, Constantinople, and beyond as far as Ismid and the Dardanelles. June 19 I returned from Constantinople, and proceeding via Budapest to Neu-Sandec, near Krakau, spent several days in the Karpathians. On the 1st of July I sailed from Cherbourg for New York.

CONFERENCE RELATIONS AND RESULTS.

Berlin.—Baron Ferdinand von Richthofen, one of the earliest and best-informed geological explorers of China, 1868–72, had in 1903 courteously advised me concerning favorable localities for investigation, and with the broadest scientific interest he welcomed the detailed

*Grants Nos. 72 and 116, $12,000 each.

facts which favorable circumstances had enabled us to gather. During my stay in Berlin room was furnished me at the Geographic Institute, of which he is director, and its facilities for study were placed at my disposal. We had frequent conferences, which led to a common understanding of the facts and in general to agreement in views.

Vienna.—At Vienna there are three scientists whose views were sought: Prof. Edouard Suess, Prof. Albrecht Penck, and Prof. Victor Uhlig. In preparing the volume of Das Antlitz der Erde which describes Asia, Suess became peculiarly familiar with Russian reports of exploration, but it was his preëminent position as founder of the theories regarding mountain structure which are now dominant in Europe which led me to lay before him the alternative hypotheses based on observations in America and Asia. Penck, the interpreter of European physiography, whose views, though original, are in sympathy with American ideas, gave me the benefit of his wide knowledge of the problems which I could but hastily scan. We made several excursions together to typical localities in Austria. Uhlig, to whom more than to anyone else we owe a knowledge of the geology of the Karpathians, not only placed his data at my disposal, but also accompanied me several days in the field.

Among others to whom I became indebted in the course of scientific work are Dr. Max Groll, of Berlin; Professor Brückner, of Halle; Professor Gavazzi, of Fiume; Professors Marinelli and Darnelli, of Florence; Professor Arturo Isso, of Genoa, and Professor Kilian, of Grenoble. Special interest and courtesy were shown by Prof. Johann Cvijic, of Belgrade, and through him by the Servian authorities, in arranging conveniences for the trip down the Danube. Professor Cvijic also accompanied me through Bulgaria and to Constantinople.

STUDIES IN MOUNTAIN GROWTH.

Character of observations.—At the present time a report of the studies in mountain growth must be limited to an outline of observations and their bearing, without adequate discussion of the evidence or presentation of alternative arguments. There are two distinct methods of investigation, the geologic and the physiographic, which supplement one another and should be combined; but the geologic, dealing with internal structures, is frequently pursued to the exclusion of the other, and the physiographic, being based on external forms, tempts the general observer to draw inferences, even where the underlying geologic relations are unknown. In either case a partial conclusion alone can result. In their present state my

impressions of European mountains may not unjustly be qualified as leaning on physiography; for a just balance they need to be supported equally in geology; but as the results of purely geologic investigation have been gathered in detail and elaborately discussed, the presentation of physiographic facts is a step toward establishing a general equilibrium, and this is the more important since the current interpretations result in different conclusions.

Geologic research, reaching only the facts of stratigraphy and internal structure, led to the commonly accepted view that mountains, considered as elevations above sea, owe their position to those forces which produced the folds or dislocations observed in the rocks. Physiographic research has, in some instances, established the lapse of an interval of time often equivalent to geologic ages between the development of the structure and the growth of the height above sea-level Mountain growth is thus recognized as a phenomenon distinct ftom and often more recent than mountain structure. This is now known to be true of those ranges of North America and Asia which have been made the objects of physiographic study; it is not generally held to be true of the ranges of Europe which have been investigated chiefly geologically.

The object of my reconnaissance was to ascertain to what extent the physiographic methods employed in America and Asia might be applied in Europe and what likeness or difference there would be in the results. I am led to think that, on the one hand, European mountains exhibit physiographic aspects which express facts of development closely parallel to those of other continents; yet, on the other, the ranges of Karpathian type are characterized by peculiarities not yet observed elsewhere and incident to the recency of folding.

The essential feature of the method of observation lies in the recognition of a topographic surface, which may be a surface of mature hills and valleys or a smoother peneplain, but which is older than the present cycle of erosion and has been warped. Originally a lowland, such a surface may be depressed and become buried beneath sediment, or may be raised and consequently eroded. In the former case the age of the sediments defines the epoch of warping; in the latter the degree of erosion gives some measure of the lapse of time, and the valley-forms yield data regarding the steady or intermittent nature of the uplifts. The depressed areas may be called *downwarps* and the uplifted areas *upwarps*, in distinction to the analogous structural terms "syncline" and "anticline." No genetic relation is known to exist between warped forms of the surface and structural forms of the internal strata.

PHYSIOGRAPHIC NOTES.

Central Germany and Northwestern Austria.—The mountains of central Germany, from the Rhine eastward, and of Austria north and west of the Vienna basin, exhibit in general an even summit surface, in which valleys are more or less developed. Penck has shown that this surface is a peneplain of Cretaceous age, and that the valleys have had a complex history involving erosion, submergence, filling, uplift, and re-erosion, during and since the middle Tertiary.

To become familiar with this type of mountains, I made observations along the Rhine, across the Thuringer Wald, along the Elbe above Dresden, on the Danube above Vienna, and in northeastern Bohemia near Zwittau. In the last two districts I accompanied Professor Penck and his students.

The interpretation worked out by Penck was verified and to some extent supplemented by the observation that the peneplain was not only uplifted, but also warped. Near Dresden it was seen sloping from the upwarp of the Erzgebirge down to and beneath the downwarp of the plains of northern Germany; and near Krems, on the Danube, a similar relation was noted with reference to the Vienna basin and the mountains northwest of it. In Bohemia the combined geologic and physiographic evidence shows that warping occurred before or during the Miocene, and in later Tertiary was followed by other warping movements, differing in direction and position from the earlier ones. And on the Elbe, in the district known as the Saxon Switzerland, the valley history consists of two episodes, one of late Tertiary date, the other Quaternary, showing that warping has there continued in notable degree to relatively recent times.

As the latest folding suffered by rocks of this general region was that at the close of the Paleozoic, the relation between folding and warping is very remote, if indeed any genetic relation exists at all.

Karpathians in Western Galicia.—Accompanied by Professor Uhlig, I visited the mountains of Oligocene, Eocene, and older strata, south of Neu-Sandec. The particular locality was chosen because of the occurrence of estuarine Miocene near that place, in a wide but deep valley, opening northward toward the plains of Russia, and of the critical relation of the Dunajec River to the structure, which it crosses at right angles.

The latest episode of folding in this region affects Oligocene strata, and the elevation of the mountain range has hitherto been correlated with it. There are, however, physiographic evidences of a more complex sequence of events, which we noted and in regard to which we

reached an agreement of views. Whatever mountains resulted from the folding, the first Karpathians, were eroded to a hilly lowland, though probably not to a well-developed peneplain. The lowland was warped, giving rise to a second Karpathian range, whose relations to the first are not determined, but they appear to be coincident in position. The Dunajec and similar streams, having developed on the lowland, maintained their courses across the later upwarp, and had worked out large valleys at the time of the Miocene submergence. These valleys then became estuaries, and above the level of the Miocene sea the tributary valleys widened, producing a well-defined terrace. During a later epoch, probably the Pliocene, the range was warped higher, and the estuarine deposits were eroded and the valleys deepened.

In this instance events are closely crowded in the Oligocene and Miocene. Subsidence and deposition were followed by folding; there was an episode of general and deep denudation; warping succeeded, occasioning renewed erosion, and then subsidence, producing estuarine conditions—all this before the late Miocene, and since then relatively slight warping.

The Danube and the Balkan Mountains.—Professor Cvijic and I followed the Danube from Belgrade to Turnu-Severin through the canyon of the Iron Gate, passed through the Iskar Canyon to the intermontane plain about Sophia, and thence proceeded by train to Constantinople.

The Iron Gate of the Danube has been an object of much study by European geologists, but not as a physiographic problem. Our contribution to the subject is therefore one of new facts and new views. In brief, we observed a pre-Miocene topographic surface, which was once a flattish hilly lowland, but which is now strongly warped and eroded. The resulting mountains and valleys are the Balkans and Transylvanian Alps. As in the Karpathians, this warping and erosion occurred in an early Miocene time, and later Miocene strata are deposited in the lower valleys. The Danube Canyon is that of the antecedent river, which, being a master stream, maintained its course across the upwarp.

This is the interpretation at least as far as Milanovac, the point whence the river turns sharply northeast and flows past Veliki Strbac, the striking peak of limestone that hangs over the narrowest and deepest part of the canyon. There is a marked difference in the features below Milanovac and those above. The former are related to a normal fault of Pliocene age, of which Veliki Strbac is the upthrown side, and we conceive the corresponding course of the Danube to be

controlled by the fault which occasioned a diversion of the river from its pre-Pliocene course southeastward beyond Milanovac.

The gorge of the Iskar exhibits features of an antecedent valley cut across an upwarp, features closely resembling those of the corresponding part of the Danube Canyon ; and the mountains about the basin of Sophia descend to the plain by sloping surfaces produced by warping that are distinguishable from sharply cut surfaces produced by erosion under existing conditions.

In general, observations throughout the journey across Hungary, Servia, and Bulgaria led to the opinion that upwarps and downwarps may be traced out on a large scale ; and in their relations will be found the key to the later Tertiary and Quaternary history. The structural history of the mountains is earlier Tertiary or older.

The Bosphorus and Dardanelles.—The vicinity of Constantinople is characterized by an extensive plain, a peneplain, which has been recognized in its true character by Cvijic, Phillipson, and Davis. An appropriate name for it is the Pera Plain. It is eroded across folded Palezoic and Eocene strata and coincides with the surface of deposition of late Tertiary limestones. Rising gently from the Sea of Marmora, beneath which it is submerged, it reaches an altitude of 200 meters above Therapia and Bojukdere, whence it descends more steeply into the Black Sea. The upwarp which the Pera Plain thus presents is crossed by the Bosphorus in a valley which exhibits all the features of a valley of erosion. Inspection of the slopes shows that the valley developed as the antecedent stream cut down into the rising upwarp. The present submergence is a later event.

East of the Bosphorus, in Asia Minor, the surface corresponding to the Pera Plain bears numerous and extensive monadnocks. The hills 10 to 20 kilometers southeast of Haida Pasha appear to rise 300 meters above the plain, and the Princes Islands are submerged features of similar magnitude. We traced this Pera surface as far east as Ismid and southwest to the Dardanelles. Our observations were disconnected, but the physiographic features are consistent throughout the region. The Sea of Marmora is a downwarp in which the monadnocks form islands. Its eastern bays, the Gulfs of Ismid and Gemlik, are extensions of the general depression between which lies a very strongly developed upwarp, forming a high mountain range, of which the higher summits are probably upraised monadnocks. The Dardanelles, like the Bosphorus, have the character of an antecedent valley, eroded by a flowing stream and now submerged ; but the course of the stream was less directly across the upwarp than was that of the Bosphorus river. The phenomena are complicated by

the more or less hilly or mountainous character of the original Pera surface, which makes it difficult to distinguish elevations due to later upwarping, and the lack of a good geologic map renders details of physiographic inference uncertain. Nevertheless, effects of warping were clearly observed in the relations of the Pera surface to the principal heights and depressions. Neumeyer showed that the Ægean is a region of recent subsidence. We regard this as a general lowering of the whole surface, following upon the local sinking and rising of downwarps and upwarps respectively.

Istria and Croatia.—The northern Adriatic is like the Ægean in being a recently sunken land. The occurrence of fresh-water deposits of Quaternary age on very small islets and of species peculiar to the mainland is evidence of this well-established fact; and, as in the Ægean, the subsidence appears to have affected an extensive area. The region is also one of very pronounced warping of an unusual type.

In the peninsula of Istria there is a peneplain, recognized before my visit by Dr. Norbert Krebs, of Triest, which is very clearly developed on the softer Tertiary rocks and to some extent on the Eocene limestones. The summit of Monte Maggiore, above Abbazia, is a monadnock, and other isolated heights and mountain groups of the mainland of Croatia hold a similar relation to the maturely eroded surface of the peneplain of Istria. The ancient topography had reached the same stage of erosion as that of western Asia Minor, when it became warped.

The evidence of warping is found in the position and attitude of the old topographic surface. Its position, considered with reference to the sea, is very variable. At Pola and along the coast from Fiume to Zengg and further southward, it rises from the Adriatic. In Monte Maggiore it attains an altitude of a thousand meters, and it lies at similar altitudes in the mountains of the eastern coast. These differences are such that the activity of erosion has been greatly accelerated, and the surface is being destroyed in consequence of the change from the low level at which it developed. There is nothing in these facts which distinguishes the particular phase of warping from that of many other districts in Europe and elsewhere. But when we trace the surface as we might a stratum, in studying a region of folded structure, we find that it exhibits downwarps and upwarps which are long and narrow and which have relations to one another similar to those of parallel synclines and anticlines. This is most conspicuous along the Croatian coast and in the islands and canals of the Gulf of Quanero. Beneath the canals the surface is submerged; they are long, narrow downwarps. In the islands the surface is slightly arched;

they are long, narrow upwarps. The trend of these flexures of the surface is parallel in a general way to the trend of folds in the Eocene and Miocene strata, across which the surface is eroded. The relations suggest a renewal of compression after an interval of erosion, and should be closely investigated to determine just what may be the validity of the suggestion.

Although in many instances the old topographic surface may be observed sinking into and rising from the sea, there are other slopes, such as that of Monte Maggiore at Abbazia and of the island of Cherso, opposite, which exhibit features of erosion characteristic of a river valley. These may be provisionally interpreted as the valleys of antecedent streams which originated on the old peneplain and maintained their courses across a rising upwarp until, in the course of later movements, the valleys were submerged in consequence of the general subsidence.

There is another phenomenon of the Croatian district which should be discussed in connection with warping. It is the prevailing occurrence of the "karsts" or extensive sinks in the limestone district and the disappearance of large rivers in subterranean channels. A typical case is that of the Gac-ko, east of Zengg. There is here a large basin, probably 15 miles or more across, which appears to be a downwarp encompassed on all sides by upwarps. The upwarp which lies between it and the coast was observed in the ascent to the Vratnik Pass, and it was inferred that warping had proceeded with such energy as to subject the river to diversion to underground channels that originated in the fractured limestones of the district with the sinking of the ground-water level.

In general this extremely interesting region may be said to show the nearest approach yet observed to a genetic relationship between highlands which originated with the folding of the strata and mountains produced by warping; yet even here there are evidences of an epoch of erosion, which intervened between the two episodes of deformation and in which the cycle reached advanced maturity or even old age. If we attempt in a general way to place these events in the geologic time scale, we may assign the folding to the late Miocene or early Pliocene, the erosion to the greater part of the Pliocene, and the warping to the latest episodes of that period.

The Northern Apennines.—Opportunities to observe the Apennines were had between Bologna and Florence, in the vicinity of Florence, and in the valley of the Serchio between the Apennines and the Carrara Mountains. The large features are simple. On the north is the great downwarp of the Po Valley, which is deeply aggraded,

yet from which, in the vicinity of Padua, a few isolated monadnocks rise. Near Bologna I observed a peneplain, diversified with many monadnocks, which, rising from beneath the plain of the Po, ascends in a broad, flat arch to the summit of the mountains, whence it descends toward the southwest to the valley of the Arno. Near Florence the old topographic surface is depressed and buried beneath lake sediments of late Pliocene age. The downwarp is but about 8 miles across at the level of the plain, and near Signa the surface rises again in the upwarp, across which the Arno has cut its lower valley. A study of the gorge below Signa showed all the features of an antecedent valley of erosion, and the peneplain was observed to sink beneath the coastal plain toward the west.

The valley of the Serchio corresponds with a similar depression between the two upwarps of the Carrara Mountains and the Apennines, which here reach altitudes of about 6,000 feet. This downwarp also contains sediments of late Pliocene age, while the tributary valleys and mountain spurs are characterized by remnants of old valley floors that mark stages in the progress of erosion during the process of warping.

For a nice analysis of these phenomena a further study of the work of Italian geologists is needed, but the observed facts form a consistent body of evidence, which leaves no doubt that, after the Eocene and Miocene strata had been folded, they were extensively eroded to a lowland, above which there still rose isolated hills or groups of hills that maintained altitudes of several hundred feet. This cycle of erosion was interrupted by pronounced warping, to which the present mountains are due, and the geologic dates assignable for the several steps of development fall within the Pliocene period, as do those of Istria.

The Alps.—The districts to which my observations were otherwise confined were non-glaciated, and consequently presented comparatively simple topographic features. The Alps are physiographically and structurally among the most difficult regions of the world, and they have been so carefully studied that exhaustive work alone is worth while. Nevertheless, in passing through them, I made observations which lead me to think that they are peculiar among the other ranges having a similar structural history only in the intensity of the phenomena. The special features which characterize mountains of the Alpine class in Europe are folds and overthrusts, which have thrown strata of the early and middle Tertiary into very complex relations with older rocks. In interpreting these facts European geologists have relied wholly upon assumptions in stratigraphy and structure and

have been led to conclusions which, though they command the confidence of the best observers, yet challenge the principles of mechanics. The problems have been studied qualitatively, but not quantitatively. and it would not be surprising if the conclusions were found fallacious when tested with reference to the capacity of thin sheets of rock to maintain their form and transmit thrust over great distances. If we may draw an inference by extending to the Alps the general conclusions based upon reconnaissance of other ranges of a similar type in their immediate vicinity, I would suggest that, like the Apennines, the Balkans, and the Karpathians, the Alps suffered erosion and pronounced warping during the Pliocene, and that the solution to some of the difficulties will be found in a proper recognition of the sequence of erosion and warping.

GEOLOGIC RESEARCH IN CONTINENTAL HISTORIES.

By BAILEY WILLIS.

PLAN OF RESEARCH IN PALEOGEOGRAPHY OF NORTH AMERICA AND EURASIA AND SUBSEQUENTLY OF SOUTH AMERICA, AFRICA, AND AUSTRALIA

The problem.—To determine the geographic condition of each continent at successive geologic epochs, from pre-Cambrian to Quaternary, and thus to arrive at means of comparison of continental histories.

The argument.—A geographic condition (*i. e.*, the distribution of sea and land—the height of land and depth of sea, ocean currents, climate, and allied phenomena, including organic life) is a transient phase of the features of the world; it may be considered as a fixed geographic state for any brief period only, but is and always has been subject to change. The energy which initiates that change is the earth's internal energy; expressed in superficial warping, it modifies the position of sea-level, causes migration of coasts, and changes heights and depths. Two processes depend upon warping, namely, erosion and sedimentation. Erosion, the destructive process, leaves only a transient record on land; but sedimentation, the constructive process, records the geographic facts. These processes have interacted continuously since an early geologic period, and the history of their interaction is to be found in strata and associated rocks. Part of the facts are original with the sediments—their distribution, constitution, and contained fossils; part of the facts are of later development—effects of concentration, folding, and metamorphism; but given the facts, we can organize, correlate, and interpret them in terms of their causes and conditions. Thus interpreted, they will yield connected views of paleogeography.

The method.—(*a*) By organizing the appropriate facts of geologic science, according to lands and times; (*b*) by interpreting them in terms of successive geographic conditions; (*c*) by delineating the several states of each continent upon maps, which shall be accompanied by appropriate discussions.

The means.—(*a*) Studies in geologic literature of all countries; (*b*) conferences with geologists, paleontologists, and specialists in allied sciences; (*c*) exploratory journeys.

The result.—A contribution to the geology of the world, as distinguished from the geology of provinces; an assemblage of facts classified by continents and geologic epochs; an assemblage which,

if considered with reference to any one continent, will give the sequence of its geographic conditions, or which, if considered with reference to any one epoch, will constitute a map of the world at that time.

The bearing.—This historical atlas of the world, summarizing all the geologic record, will constitute a work of reference upon which to base discussion and research in all departments of geology. Summing up available evidence, stating alternative interpretations, giving conclusions where facts are conclusive, but justly weighing doubt, the publication should promote advance in the science in the highest degree and should itself advance with the science. Correlation of strata and faunas, the crux of geologic historical investigation, is involved in the proposed research; but the facts of geographic variations, once placed in sequence, will throw much light on its problems. Organic evolution is studied without reference to the important factor of environment so long as we have no definite knowledge of the shifting lands and seas, which have been the scene of its conflicts; this contribution of paleogeography will place it upon a foundation. The problems of those climatic fluctuations which have ranged from tropics in the Arctic to glaciation near the Equator remain indeterminate so long as the geographic variable is unknown. That variable should be evaluated by this research. The initial cause of continental variations, intermittence of the earth's internal activity, will be followed throughout geologic time, and the contribution to epeirogeny and orogeny will thus constitute also a contribution to the data of geophysics. The proposed research, if broadly, liberally, and judiciously executed, must serve students in all branches of geology and in many of its allied sciences.

DISCUSSION.

Data available for interpretation.—Geologic literature contains a large amount of data relating to the proposed material. Stratigraphic sequences, structural relations, and paleontologic correlations yield the facts with which the paleogeographer begins, and he should base his work, so far as possible, on the results of geologic surveys already accomplished. For the United States and Europe the existing material is adequate to furnish a tolerably complete conception of the continental histories, and the same is true, though in a less degree, of Canada and Mexico. The literature relating to South America, Asia, Africa, and Australia is sufficient to afford a suggestive outline of continental conditions at different times, through which we may arrive at an understanding of the critical localities for further research.

This material is published in the various European languages and can not all be assembled readily by any one student; but it is now more accessible than formerly, through the bibliographic work of the French and Germans during the last ten years, and it is possible to direct investigations where the limitations of language or time prevent personal study. In addition to that which is published, there is a large body of knowledge reserved by students, yet accessible through personal conference, and this also it is hoped to reach.

Field investigations.—Inasmuch as the available data are neither free from contradictions nor complete, provision should be made for field work to carry out (*a*) supplementary observations and (*b*) exploratory surveys. Supplementary observations may be required to review controverted questions, and the most profitable method is that of a field conference.

Exploratory surveys, such as that made in China during 1903 and 1904, will be necessary in the less-known regions of the world, but in view of the large expenditure of time and money which they may occasion, their number should be limited and they should be undertaken only when definite questions have been formulated and where decisive results may reasonably be expected. Unknown Asia, Africa, and South America will contain such districts, of which we shall obtain cognizance as we develop their histories according to existing knowledge. Northern Mexico presents a special problem which may serve to illustrate the need of less extended field work. In the Lower Cretaceous we have, in Texas and California, two distinct faunas apparently contemporaneous. Stratigraphic evidence, so far as known, suggests a connection between the then existing Atlantic and Pacific waters. Why, then, are the faunas so unlike? A reconnaissance should suffice to trace the line between the faunal provinces and to determine its character; and at the same time observations should be made on the geology of this little-known region, which would enable us to sketch the lines of continental history through the geologic ages. This is a definite problem, requiring the work of a stratigrapher and paleontologist in association in a district which can be narrowly delimited.

Indeterminate questions.—There are two conditions which will give rise to indeterminate questions. One is the undeveloped state of the science of paleogeography. Although loose generalizations based on stratigraphic facts have been common, refined interpretations have not been. We have yet to develop many of the criteria by which to discriminate nicely between different geographic conditions that are recorded in similar strata or dissimilar faunas, and thus we shall find

it necessary to state alternative hypotheses in cases where the conclusion can best be left to a more advanced state of knowledge; but it is to be expected that we may gain as we put the alternatives.

The other condition of indeterminate questions is incompleteness of facts. It is partly incompleteness of the geologic record, from which many sections are missing; it is also partly the state of geologic exploration, which still fails to cover, in an adequate degree, large areas of several continents. We can not restore the missing parts of the record, yet a fuller assemblage of the existing parts should enable us better to understand what they might signify. We can not attempt to survey the world, but by studying the available data we shall arrive at a better knowledge of the critical districts where surveys will reap the largest harvest, and some part of these surveys we may make.

METHODS OF RESEARCH.

The methods of the proposed research comprise (*a*) assembling data of stratigraphy, paleontology, and orogeny; (*b*) interpretation; (*c*) correlation; (*d*) delineation of results on maps and discussion of mooted points in manuscript.

Assembling.—To assemble the data requires extensive reading, which should be planned, first, with reference to a definite province, and, second, according to geologic epochs. A record should be kept in classified notes and on index maps, and these will serve as a basis of compilation on provisional and final maps.

Assume that we are considering the Appalachian province of North America, and are beginning with New York State, the best-known district. The geologic map gives the distribution of formations of many kinds and many epochs. Each formation exhibits characters (constitution, texture, color, bedding, surface markings, and contained fossils) which are peculiar to the conditions of origin of material, to the conditions of transportation, and to the conditions of deposition. The interpretation of these will be considered in the next paragraph. We are now concerned with assembling the facts. The geologic map is a composite picture. To analyze it we select formations which mark successive geographic conditions and map each formation separately, noting not only its distribution, but also variations in its characters. The data must be gathered not only from the original geologic map, but also from the literature. There will result a body of material (maps and notes) which should be kept classified for convenient reference and comparison, as the study extends to other districts of the province. In so large a work as is here proposed, to extend over years, it is important to arrange the

original data, the raw material, systematically. Gaps in the evidence may later be filled in, reasons for controverted inferences may be called for, revision of views may become desirable, or the investigation may pass into new hands. In any case the original assemblage of facts should be well ordered.

Interpretation.—Interpretation is deciphering the record of geographic conditions embodied in sedimentary strata and associated rocks, according to the processes of epeirogeny, erosion, and sedimentation. We proceed from the certain to the uncertain. Thus, given the area of occurrence of a sedimentary formation, we know that there was a coextensive water body; given a change in thickness and constitution, a change which takes place in a definite direction, we may state in what direction lay the source of the sediment, a land area; given those peculiarities which are characteristic of the littoral, we may approximately delineate the position of the shore zone, and thus delimit land and sea for that area and that epoch. Thus far we may often proceed with reasonable certainty, since we deal with a definite condition which admits of no alternative, and thus far, but no further, geologists have usually gone; for they commonly leave untouched the problems of physiography and climate during a specific epoch, or the sequence of migration and fluctuation of conditions from age to age.

In reference to physiography we may state as our guiding principle that the volume of sediment deposited in a given area during a certain epoch is a function of the area and altitude of the land from which it came. For instance, strata of the Devonian age in Alabama are but 30 feet thick; in Pennsylvania strata which correspond in age are 10,000 feet thick. There is evidence that the shore was not notably farther from the one than from the other deposit; but clearly in one region the nearby land, though possibly extensive, was low and yielded almost no sediment, whereas in the other district it was not only extensive, but also elevated. In Pennsylvania and adjacent States the character of the sediments, that of sandy alluvium, bears out the inference that they came from a mountainous region, whence large rivers flowed to the sea, and as the volume of strata is equal to that of a Sierra Nevada, we have a suggestion of a vanished mountain range that rose somewhere along the eastern border of the continent, probably where now is the western Atlantic.

A contrasting physiographic inference is that which relates to both North America and eastern Asia during the Cambrian period. At the base of the Cambrian series in each country is a stratum of mechanical sediment, spread by the sea which swept over thousands

of square miles of land area. Whatever mountains had previously existed had been eroded and continents, worn down to plains, sank and were submerged. Strata deposited in those wide seas in America and Eurasia were to a great extent limestone; terrigeneous sediment was not delivered in any quantity during a very long period; the physiographic aspect of surviving lands was that of the Siberian plains, the lowest, the most monotonous; there were scarcely any mountains, so far as we know the continents.

In reference to climatic conditions we may interpret the chemical and biological characters of strata in terms of aridity and cold or of humidity and warmth. Chamberlin has pointed out the way in his papers on the grouping of red beds, saline deposits, and desert conglomerates in distinction to those sediments in which the oxides were reduced in consequence of the presence of vegetation, or in contrast to great limestone deposits from warm seas teeming with life. That such grouping occurs in repeated sequences from pre-Cambrian to the present is established; the criteria still demand much study, and there are problems, such as the surprising deposits of gypsum in Oklahoma, for instance, for which, as yet, no adequate explanation is advanced. The last word has by no means been said in simple stratigraphy, and in this comparative study it is part of the task to develop the residual questions.

Thus far in discussing interpretation we have suggested only individual formations, which are taken as illustrations of fixed conditions; but fixity is temporary in paleogeography, constant change is the law for longer time divisions, and successive conditions are recorded in sequences of strata. Where an individual fact or group of facts is unintelligible when isolated, it may be understood readily when placed in relation to those which went before. For instance, the volume of vein quartz represented by the sand grains and pebbles of the Carboniferous sandstones, either in Europe or the United States, could not have been derived in any one epoch of erosion from the gneisses which were its source. But this concentration of quartz follows upon strata which are littoral or off-shore deposits, yet are without those coarser beach sands that must have been formed near shore contemporaneously with them. While these earlier formations were accumulating, a coastal plain was the locus of concentration of the relatively indestructible quartz, and this concentrated material ultimately went to form the great mass of sandstones, which accumulated in the Carboniferous basins. Thus the coastal-plain deposits of Silurian and Devonian continents are in part found resting upon strata of those ages in that conformable sequence in which they were redeposited in consequence of geographic changes and erosion.

The broader results of this research are found in the comparative studies which trace for one age the geographic condition of all lands and pursue through all ages the geographic history of the earth. To illustrate: In Cambrian time, North America and Eurasia became to a great extent submerged. Was this true of other continental areas? Throughout the northern hemisphere there ensued a long period of rest from mountain growth. Was this a general condition of the whole earth? During a succeeding period, the Silurian, geographic changes were frequent and complex; land areas were larger; in some districts mountains grew and were eroded. To what extent were these manifestations of earth-warping general? Following the course of geographic history through succeeding ages, there is, for lands where we know the geology, an apparent periodicity; extensive seas and low lands alternated with limited seas and higher lands. These are evidences of intermittence in the earth's internal activity, and if they should be shown to be general we would arrive at an important line of inference regarding the manifestation of the energy.

This suggestion of periodic warping has an important bearing on organic evolution. In the wide, shallow seas of a long period of quiescence, life was favored and kinds multiplied; in the shrinking, deepening seas of an epoch of warping, the stress of limited habitat was great, and the destruction of many forms resulted. Migrations with expanding habitats, retreat, and extinction with lessening seas or lands have influenced life histories, and we shall find in better knowledge of such causal conditions a better understanding of the obscure problems of paleontology.

Climate also is probably variable as geographic conditions vary, and one object of interpretation of continental histories is to determine the importance of this relation.

Correlation.—Within the narrow limits of a geographic district, for whatever period of time there exists a continuous sedimentary record, we may read the events of that local geographic history without necessarily referring them to divisions of the world's geologic calendar; but to compare parallel provincial histories we must correlate contemporaneous events, not only for each continent, but also for all continents.

The means of correlation are facts of stratigraphy, paleontology, climatology, and epeirogeny. This enumeration is not only in the order of their recognition during the growth of our science, but also, in a measure, according to their nearness to a fundamental cause. The physical characters of strata, which are remote effects of a

series of processes, were first used as means of correlation. The "Old Red" of Scotland was correlated with that of New York because they were both red sandstones. The comparison of species, genera, or faunas is the means now relied upon. It has the advantage over stratigraphic evidence that in the course of organic evolution there has been no repetition, but it is not without the difficulties which result from the dependence of life upon conditions that follow from successive processes. The differentiation of faunas, their migration, their appearance in new districts, their retreat, reappearance, and extinction, are not simply facts of life history; they are conditioned by environment and depend upon the transiently fixed or shifting geographic conditions. The advent of closely related species in districts remote from one another may or may not be contemporaneous. The episode of migration, commonly neglected, may or may not be negligible, and its value can not be reckoned until we have compared the geographic histories of different lands by the aid of other criteria of correlation. The interdependence of stratigraphy and paleontology follows from their common relation to the progress of geographic variation, back of which lies the general cause, earth-warping.

A broader basis of correlation has been sought by Chamberlin in world-wide physical phenomena, immediately in fluctuations of climate, more remotely in variations of continental extent, the underlying assumption in each case being a periodicity of activity in earth-warping. This hypothesis is a relatively recent contribution to the philosophy of geology and stands to be tested. Not only it, but also the data of paleontology, will be tried when we are able to place in evidence the parallel history of continents. Correlation is thus both a method of interpretation and an object of investigation in the proposed research.

Delineation and discussion.—The contribution which may be made to science should be embodied in maps and reports. The available maps should be issued from time to time in the progress of the work in the form of atlases, each of which should contain related deductions, and with each atlas should be issued a volume of discussion summarizing the evidence and giving the grounds of inference with qualifications.

In assembling the results on maps, the methods adopted should provide for adequate expression of the range of inference from doubt to conclusion. Each map will represent the condition of a given region during a certain geologic age. Areas known to have been land and sea will be distinguished from those supposed to have been one or

the other; on land areas, coastal plains, interior plains and basins, and mountain districts may be distinguished, and for seas we may delineate the nature of accumulated sediments, the courses of ocean currents, and, in cases of expansion or retreat, the direction of migration of shores. Thus for a given region or continent a set of maps will present the sequence of physical conditions from an early period to the present, or, for a particular period, the maps of all the continents will offer a conception of the world's geographic condition.

In the discussions, facts and theories should be rigorously separated; alternative views should be given appropriate expression, and the contribution to paleogeography should thus present in graphic and verbal form a clear account of the earth's history, so far as we may yet understand it.

ORGANIZATION.

The organization here proposed is designed to be small, but efficient and elastic. It comprises a geologist, paleontologist, associate investigators, and aides in the office and field.

The geologist.—The geologist should be in charge of the research: upon him should rest the undivided responsibility to initiate plans within limits of cost, devise methods, employ assistants, direct the work, and state the results. The broadest knowledge of geology in various branches would be none too broad, but his special training should be in stratigraphy, structure, and physiography, the principal sources of evidence for this research.

The paleontologist.—A good foundation in general paleontology and a broad grasp of the science are the qualifications needed in this associate. Since paleontologists are usually specialists in minor divisions of that study, it is not probable that one man can be found to give an expert opinion on the evidence affecting each particular question which will arise in course of investigations that must cover the range from Cambrian to Quaternary; nor is the expert specialist the man wanted in this position; he belongs among the associate investigators; rather is the man that one having broad knowledge and a liberal mind, that one who will weigh justly the arguments of specialists. A young man of adequate education, fitted to grow with the work, will probably give better satisfaction than an older one.

Associate investigators.—The scope of the inquiry being world-wide and, its range being that of all geologic time, it embraces more than the knowledge of any few men. Coöperation with geologists of all countries is essential to completeness and success. Such coöperation may vary from an expression of opinion to more or less extensive

investigation; the cost of minor items may be met from the general fund granted for the research; larger expenditures may be made the object of special grants. It is anticipated that the latter may constitute a large item of expense, but each major associate investigation may under this plan be considered on its merits. The work of associate investigators should, however, in all cases be directed by the geologist in charge.

Office force.—There should be a permanent clerk to take correspondence, to handle accounts, and keep records. It is desirable that he should read and write French and German. One or more draftsmen, at first needed only occasionally, would later be employed continuously in drawing base maps and preparing illustrations. One or more compilers to assist in examining publications should be employed as required.

Aides in exploratory surveying.—As the plan of research contemplates exploratory work, such as was carried out in China during 1903-1904, the organization of a party would from time to time become necessary. The particular organization would depend upon circumstances, but the need of services of a topographer, of a geologic assistant, and of laborers, packers, or servants usually employed in the region under survey, may be foreseen.

ORDER OF RESEARCH.

The following plan of research for a decade is based on current progress in paleogeography and in geologic science in Europe and America. North America presents the geologic record in broad features, and we are better able to outline its history than that of Eurasia. Thus by beginning with it we shall sooner reach results which may invite discussion and prepare the way for work abroad. An alternative plan, that of selecting a geologic period, say the Cambrian, as the subject of study and exploration, to the exclusion of other periods till that had been considered for all continents, has been set aside as an ultimate rather than initial classification of work.

1906, 1907, 1908, and 1909.—Studies in paleogeography of North America and preparation for work on Eurasia: Preliminary work has been done for this continent by Chamberlin, Salisbury, and others. The results are at best outlines, which leave much to be accomplished by further research, yet they serve to define our ignorance and to suggest investigation. We are able to sketch North America as a whole at twenty different epochs or more, from the Cambrian transgression to the Quaternary ice-time; for critical

provinces such as New York, additional local maps may be drawn to express details of shifting geographic phases.

Parts of Mexico, of the western United States, and of Canada are geologically unknown and invite reconnaissance surveys, to which we may assign eighteen months out of the four years allotted to the task. The work in this country might be accomplished through coöperation with the United States Geological Survey.

Concurrently with work on North America, reading and correspondence with foreign colleagues should be carried on in preparation for the succeeding work on Eurasia.

1910, 1911, 1912, 1913, 1914, and 1915.—Studies in paleogeography of Eurasia and preliminary work on the other continents: One year to supplement earlier studies in the geology of Europe; a year and a half in Europe for observation and conference; a year and a half in Asia engaged in exploratory surveys, and two years to supplement data and prepare for publication.

Studies in European paleogeography involve difficulties which arise from language, controversy, and the complexity of the later geologic history of the continent. Asia presents extensive unexplored areas and the great questions of mountain growth, which must be answered before we can understand the Himalayas and the Tibetan plateaus. It is difficult to foresee what advance may be made in a given time. When four years shall have been spent in accumulating material for study and publication, much of it from European literature, some of it from original observation, the two years remaining may well in large part be occupied in preparation for publication.

In general, it is believed that it will be advantageous to publish results at intervals, even though incomplete, and thus to benefit by that general discussion which the work should invite.

During the decade which it is estimated may thus be advantageously devoted chiefly to studies of North America and Eurasia the other continents should not be neglected. In order that we may have a rounded conception of our subject, we should know the available facts regarding Africa, South America, and Australia, and should be prepared to project plans for further investigation in those continents. Whether those plans should necessarily await the completion of the work assigned to the first decade or might advantageously be undertaken through competent associates during that time, is a question for future consideration.

ARTESIAN WATER CONDITIONS AT PEKING, CHINA.*

By Bailey Willis.

THE SITUATION OF PEKING.

Before entering upon the investigation, of which the results are stated in the following pages, the writer deemed it improbable that a supply of good water could be obtained at Peking by a deep well. Accepting von Richthofen's theory that the Plain of Peking was composed of material chiefly carried and deposited by wind, he saw no opportunity for the occurrence of strata of coarse and fine material, such as are favorable to artesian conditions; but the facts observed are convincing evidence of the fluviatile formation of the plain and of its heterogeneous bedded character. Good water is found by wells 200 feet deep, and all the desirable conditions of an artesian fountain may probably be secured by a well 1,000 to 2,000 feet deep. In the absence of any supply of wholesome water, such a well is of vital importance to the American Legation, and, as demonstrating the resources within reach, would be a boon to the entire city.

The Bay of Peking.—The great plain of eastern China, in latitude 40° north, reaches into the mountains in the form of a bay, which is 45 miles across at its mouth on the southeastern side and extends 30 miles in a northerly direction. It lies across the trend of ridges whose opposed sections form parts of otherwise continuous ranges, and the level plain is related to the mountains about it as an arm of the sea is to lofty shores. This embayment is aptly called the Bay of Peking, as the city of that name is situated at the mouth of it.

Rivers.—Two large rivers, the Pei and Hun, together with several smaller ones, enter this bay, flowing in general southerly courses. The Pei and the Hun have wide branching headwaters in the mountains. They are subject to floods and carry large volumes of sediment. The Hun is said to be the larger stream in the rainy season, though it is considered a tributary of the Pei. The relative altitudes of the two show that the Hun has deposited more sediment than the Pei.

Peking is situated between the Pei and the Hun, 14 miles west of the former and 10 miles east of the latter, the American Legation site being taken as a reference point in the city. It is about 12 miles southeast of the base of the Western Hills and from 25 to 40 miles distant from mountains on the north, northeast, and east. The open plain slopes very gently away to the south and southeast.

*The investigation on which this report is based was made on request of Hon. E. H. Conger, United States Minister to Peking, for the State Department, by authority of the Carnegie Institution. The report was submitted to and is here published by permission of the State Department.

Altitudes.—The altitude of the Belgian Railway station west of the Ch'ién-mön is 45 meters, or 147 feet, above sea, according to official records furnished by M. Jadot, director of the railway. The American Legation site, near by, is a trifle higher, its altitude being about 155 feet above sea. By the same authority the altitude of the railway bridge over the Hun River at Lu-k'ou-kiau is stated at 66 meters, or 215 feet. The height of the bridge above the river being about 15 feet at low water, the river is in round numbers 50 feet above Peking.

The available figures for the relative elevations of Peking and the Pei River are based on readings of two aneroid barometers, one being read at Peking, the other being carried to Tung-chóu and read there as well as at Peking. It appears that Peking is 60 feet, more or less, above the plain of the Pei at Tung-chóu.

The altitudes of mountains immediately surrounding the Bay of Peking, as determined by the Intelligence Branch of the British North China Command, range from 1,500 to 4,200 feet above sea. The mountains are very sharply sculptured, are exceedingly steep, and descend without notable foothills to the plain. Their rocky slopes continue beneath the alluvium of the plain. Spurs extend out into the plain like promontories into a sea, and isolated hills rise like islands through the deposits in which their bases are buried.

THE PLAIN OF PEKING.

Surface features.—To the unaided eye the Plain of Peking appears to be a monotonous level, in which artificial elevations are conspicuous because natural ones are wanting. Instrumental observations show that there are considerable differences of level between widely separated points, but the slope by which they are connected is so slight as to be inappreciable. Streams in their natural channels are rarely sunk a yard below the surface of the plain, which frequently descends slightly in a direction away from their immediate banks.

Hills which rise above the plain are of three classes—those which are the tops of partly buried mountains, those which are dunes of drifting sand, and those which are artificial. Among the latter is to be classed the so-called Coal Hill, in the Imperial City, according to the testimony of the most reliable observers.

The level of the plain extends, with remarkable uniformity, almost and sometimes quite to the base of the mountains, but wherever a ravine or valley opens onto it the surface is raised by deposits of gravel and sand from the mountain stream. These deposits constitute an alluvial cone, as it is called, which merges into the general imperceptible slope of the plain. Where many small ravines lie near together, their alluvial cones become continuous and constitute a belt.

The head of an alluvial cone may lie high upon the mountain side, and in some instances such a one has been chosen as the site of a monumental tomb. That of Ch'i-yu-fön, 20 miles northwest of Peking, is a striking instance; the Ming Tombs are in part similarly situated.

Constitution of the plain.—It will be noted that the plain of Peking is the surface of that earthy, sandy, and gravelly material which fills the embayment in the mountains. The constitution and arrangement of this material is of fundamental importance in the question of underground waters which may be reached by a deep well, and it has been made the object of such observation as is possible without boring. At Peking the surface, so far as can be seen, is composed of fine silt and sand. It has been worked over in the gradual growth and decay of the city or cities during ages, until its original condition and arrangement are lost. It is stated on good authority that foundations of old houses are found 25 feet below the present level. Three miles west of the west gate of the Chinese city, on the road to Lu-k'ou-kiau, very coarse gravel, mingled with fine sand, begins and is continuous thence to the Hun. This gravel is plainly the material distributed by the Hun in its latest excursions over the plain, together with dune sand and dust blown from other areas.

The valley of the Hun was examined as far up as San-kia-tién. It consists of an inner canyon of unknown depth, which is nearly filled with sand and gravel, and of an outer valley of moderate width.

In the northwestern part of the Bay of Peking the base of the mountains was skirted for 8 miles, from Chai-k'ou to Yang-fang. Near the hills connected alluvial cones constitute a continuous zone of coarse gravel, which gives place, a mile or more further out, to a belt of sand, on which are situated the towns named Ch'ién-sha-kién and Hou-sha-kién, *i.e.*, Front Sand Town and Back Sand Town.

From Yang-fang to Chang-p'ing-chóu, a course of 7 miles northeast across the several streams which form the Sha, or Sandy River, the western branch of the Pei, the plain is nearly level and is composed of sandy loam. This loam packs hard, cracks in drying, and is separated by the wind into two parts: fine dust which rises in clouds in the air and sand which is blown along the ground.

From Chang-p'ing-chóu east to T'ang-shan Hot Springs, 10 miles along the mountain base, coarse wash from the hills lies in a belt north of a zone of sand and sandy loam, in relations like those noted along the western side of the bay.

From T'ang-shan south to Peking, 18 miles down the central line of the bay, the prevailing material is sandy loam like that already described. South of each of the streams flowing east is, however,

a belt of sand, sometimes forming dunes 10 feet or more in height. These zones are produced by the north winds, which sweep the sand from the wide, slightly hollowed channels, in which the water is but a thread during much of the year, though a flood for a brief season.

Summing up these notes, it is apparent that the Bay of Peking is surrounded by a zone of coarse gravel next the mountains, within which lies a belt of sand also washed from the mountains, and that the great central area consists of fine sandy loam of a rather compact nature. This loam, on being redistributed by wind, gives rise to local sandy tracts and to dust storms.

Origin of the plain.—From the preceding description it will be seen that the Plain of Peking is the upper surface of a body of material which fills a depression among the mountains as water fills an embayment along the coast. It appears also that the surface as we now see it is composed of wash deposited by rivers, together with local formations produced by wind. To these facts we may add the conception, concerning which geologists in general would agree, that the land formerly stood higher with reference to sea level and has gradually subsided.

During this subsidence the sea and the rivers have been in constant conflict, the sea ever seeking to spread over the sinking land, the rivers ever bringing down sediment to build out the land. The delta of the Mississippi or the Nile or the Huang-ho illustrates the work of the rivers.

The subsidence and the filling-in have progressed gradually. There has been abundant time for the work of subsidiary activities on the surface of the filling, and we may thus conceive of the material beneath the present plain as having been spread and redistributed by streams and winds, as we now see it spread and distributed. At any particular stage of the process, at any level, there was coarse gravel near the hills and resting on bed-rock, there was sand along its inner margin, and the central area of the plain was composed of irregular stretches of sand and fine silt or clay.

A drill-hole sunk through this deposit should pass through many layers of clay, sand, and gravel of various textures and mixtures. Some may be small in area and isolated; others may be very extensive and connected with strata at much higher levels. The lowest, next to bed-rock, is probably the most extensive, as it must underlie the whole plain, the most open because it consists of the coarsest materials, and the one reaching to the highest levels, since it extends up onto the present mountain slopes.

Water may be found in any of the sandy layers. An artesian flow is most likely to be secured from the deepest.

Depth of the filling.—Data for estimating the depth of filling of the Bay of Peking are meager, but not altogether lacking. The depression is recognized as a sunken valley, sculptured by running water. There are many examples of similar character and of like magnitude in the neighboring province of Shan-tung, and some of these have not been so filled as to hide the floor of the valley. The valley of the upper Wön-ho, near Lai-wu, east of T'ai-an-fu, is many miles across, is nearly flat over considerable areas, and is diversified and bounded by mountains which rise abruptly from it. The bed-rock is widely exposed. Reasoning from this comparison, we may infer that the slopes of the mountains about the Bay of Peking descend to a depth, which is probably not excessive, beneath the plain, and are connected by a comparatively flat floor. The fact that so large an area as the Bay of Peking has been filled by streams which, though of considerable size, are not great rivers is an argument in favor of comparatively moderate depth. At Peking it may be 1,000 feet from the surface to bed-rock ; it probably is not 2,000 feet.

THE WATERS OF PEKING.

Surface waters.—A small stream, the Tung-mi, enters the city from the northwest, feeds the canals and lakes in the Imperial City, and flows away through the Chinese city to the Pei River. It has no value as a source of water. Wells are numerous in Peking. Some of the principal ones in use by the natives are seen on the streets. The deep grooves made by the ropes in the stone curbing testify to their constant and long-established use. They are shallow, are supplied by percolation in the uppermost strata, including the surface waters of the streets and houses, and are liable to go dry.

On the site of the American legation two wells have been sunk in the course of operations for building. The first proved inadequate. The second, 100 yards from the first, was sunk 32 feet, at which level water poured in in such amount that the work had to be stopped. The bottom is reported by Mr. S. H. Nealy, the architect in charge, as being a quicksand which had a tendency to flow to the southeast. This well has not been lowered by any draft thus far made upon it.

Japanese "artesian" wells.—Wells, which are artesian in the sense that they reach flows beneath the surface waters, have been sunk by the Japanese in Peking with marked success. Regarding these the following facts have been ascertained :

A well in the Presbyterian Mission Compound is fitted with a windmill and is reported to yield a satisfactory supply.

A well in the Belgian Legation grounds is said by the Belgian Minister to be 60 meters (195 feet) deep, and to give excellent soft water.

Regarding a well in the Methodist Mission Compound, Dr. I. T. Headland furnished the following facts: It is 210 feet deep, about 2½ inches in diameter, and is supplied with a reservoir set in the ground which is 15 feet deep and 3 feet in diameter. The well was sunk by churning with bamboo poles shod with iron, without the aid of machinery. Yellow clay was added with water to prevent the sand from caving, but there was some trouble from that source. The bore is lined with bamboo, the joints being secured together with tin. The reservoir is built of cedar staves, and the bamboo tube is packed around with cork to make a tight joint where it passes through the bottom of the reservoir. The bottom of the well is in black sand. The water is soft and the supply has been entirely adequate for the demand of eight American families and about five hundred Chinese. It has hitherto been drawn by hand, but a pump and elevated tank are being installed. The well cost $1,200 in silver, or something less than $600 gold. It was finished in the spring of 1902 and its life is estimated at twenty years at least.

From the evidence of these three wells, which are somewhat widely spaced, it may be inferred that there is beneath a considerable part of Peking, at a depth of about 200 feet, a stratum of sand which is water-bearing. As the water does not rise above the surface, it is not confined in an artesian basin, or it comes from a source not notably higher than Peking. As it is unlike the surface water in the city, it is probably separated from the latter by an impervious stratum of clayey loam, and, being soft, it probably enters the ground in one of the sandy zones north of Peking, whence it flows, chiefly in similar material, southward, underground. Its source may be in the vicinity of the Sha-ho.

Rainfall.—Inquiries regarding the annual rainfall at Peking have not met satisfactory answers. It appears to be irregular in amount, there being extremes of wet and of drought. Dr. N. S. Hopkins, of the Methodist Mission, stated that measurements at a station some distance northeast of Peking gave 56 inches one year and only about one-eighth of that amount the next. During wet years the ground becomes saturated. During the dry years it is to a greater or less extent emptied by evaporation and seepage. The deeper waters are, no doubt, more constant than those near the surface.

There is good reason to believe that there is within reach of the people of Peking an adequate supply of wholesome water which may be reached by boring to moderate depth.

DECEMBER 15, 1905.

GEOPHYSICAL RESEARCH.

ELASTICITY AND PLASTICITY OF SOLIDS.

George F. Becker, U. S. Geological Survey, Washington, D. C. Grant No. 172. (For first report see Year Book No. 3, p. 80.) $7,500.

Investigations for the purpose of determining experimentally a relation between stress and strain were begun early in November in the Washington Monument. A 3-inch tube 480 feet in length had been attached to the steel framework which forms the elevator shaft. The tube was closed at the top by a plate, to which the specimens to be tested were attached. At the bottom the tube projected through the ceiling of a small room that had been built as a temporary laboratory. In this little observing station were placed various pieces of physical apparatus, such as storage batteries for light and a meter-bar and cathetometer to be used in making the measurements.

The general plan of conducting the experiments was to suspend two wires 1 mm. in diameter in the tube at a distance of about 3 mm. apart. Loads were applied to one of the wires, the other one serving to indicate the linear expansion of the strained wire due to changes in the temperature. A mark was placed near the lower end of each wire, and the distance between these marks, which is evidently the total increment corresponding to any particular load, was measured with the cathetometer. The plan was first entertained of using copper wires and annealing them electrically. This plan was finally abandoned on account of the difficulty of protecting the copper against rapid oxidation, and also on account of a considerable lack of uniformity in the cross-section of the specimens. It was therefore decided to subject them to overstraining, a process which hardens the material and raises the elastic limit. This treatment proved to be unfortunate, as the wires did not completely regain their equilibrium after a period of two months had elapsed. The relative motion of the two wires became negligible, however, for short intervals of time, and systematic observations were begun in April, the loads employed ranging from 25 grams to 600 grams. The total increment in length produced by a load of 600 grams after an interval of time of ten minutes was found to be 0.9 cm., a strain of 1 in 15,000.

The deviation from Hooke's law, even with these small strains, is clearly perceptible—a result never before established experimentally, so far as I know—but the exact determination of the stress-strain relation requires the use of larger strains. Successive loads were then

applied (and removed) at intervals of 100 grams, from 100 grams to 1200 grams, inclusive. It was found, as is well known, that the strain due to any particular load was dependent upon time. If the strain is plotted as ordinate and the time as abscissa, the time-effect curve passes through the origin, is concave to the axis of time, and ultimately becomes asymptotic to a line parallel to this axis. A unique solution of our problem would consist in finding the relation between the successive ordinates to these asymptotes, as their ordinates represent the amount of strain which takes place in an infinite time. This work has not yet been completed, but a thorough investigation of the curves is being made with good hope of determining their complete analytical representation. For the after-effect, or the time-effect on wires newly released from stress, I have found a satisfactory analytical expression.

At present, steel tapes (cross-section ¼ inch by 0.007 inch) are being used instead of copper wire. The obvious advantages are that the tapes are more nearly homogeneous, they do not require to be overstrained in order to be brought into the elastic state, and, finally, steel is probably the material which corresponds more nearly to that of the interior of the earth. A series of experiments was begun on August 10. Successive loads at intervals of 10 kilograms are being applied, and the time-effect curves determined as before. The attempt is being made to continue the observations until the strain becomes almost independent of the time, thus diminishing the error due to extrapolation. The total increment in length due to a load of 20 kilograms is 13.7 cm. The time-effect is 0.07 cm. It seems to be possible to attain the degree of accuracy in measurement that was anticipated, namely, 0.01 mm., or a strain of 1 in 15×10^6. This is approximately the same order of magnitude as obtained by the use of interference methods. The time-effects tend to delay the progress of the work in so far as the determination of the stress-strain relation is concerned, but information in regard to these phenomena alone is very valuable. The labor and expense of continuing the experiments will be comparatively small, as in general only two or three observations a day are necessary, and these can be made without materially interfering with the progress of other work.

Attempts have been made to determine a stress-strain relation for some anomalous substances, such as catgut and a pseudo-solid composed of pure albumen and sugar. The experimental part of this work is almost completed. A few preliminary experiments have been made on crystals with interesting results.

Dr. J. R. Benton resigned in August to take a professorship of physics, but desires to continue work on crystals in connection with the general investigation. Mr. C. E. Van Orstrand was then put in immediate charge of the observations and Mr. H. B. Ayres was engaged to assist him.

Dr. Benton has written a paper on the experiments on catgut which is printed in the American Journal of Science. No other material is as yet wholly ready for publication.

PLANS.

The conditions requisite to an experimental determination of a stress-strain relation are (1) a constant temperature and (2) a high degree of accuracy in the measurement of the strains. The last condition may be obtained by measuring a large elongation with a fair degree of accuracy, or by measuring a small elongation with a high degree of accuracy, for example by the interference method recently used by Mr. Shakespear. It is probable that the stress-strain relation obtained from experiments on small specimens is dependent upon the cross-section of the material. It is well known that small specimens show a tendency to yield abruptly in the vicinity of the point of the so-called limit of elasticity. It is highly probable that no such point exists, but that the transition from the elastic to the plastic state is continuous, beginning at the instant when the smallest load is applied and continuing up to the point of rupture. In order that the investigations be conclusive, therefore, it is desirable that experiments be made upon both large and small specimens. The conditions at the Washington Monument are perhaps the best that can be obtained anywhere in the world for conducting the experiments on a large scale. Some preliminary experiments have been made to ascertain the feasibility of measuring the strain in small specimens by means of the interference method in our laboratory. It is possible that the vibrations in the building may be sufficient to prevent observations being made, but apparatus is being designed which it is believed will prove to be satisfactory. Attempts will then be made to determine the stress-strain relation for small specimens of crystals, and wires and ribbons of various metals. If the experiments prove to be satisfactory the same apparatus will be used in connection with an electric oven to determine the variation of Young's modulus with temperature.

MINERAL SOLUTION AND FUSION UNDER HIGH TEMPERATURES AND PRESSURES.

Arthur L. Day, U. S. Geological Survey, Washington, D. C. Grant No. 225. (For first report see Year Book No. 3, p. 80.) $15,000.

At the time of the last annual report the laboratory rooms had been occupied only three months, and nearly all of our energies and resources were being concentrated upon the designs and construction of the permanent plant. A considerable portion of the work of this year and of the allotment has necessarily been devoted to the same purpose. About one-fourth of the sum ($15,000) allotted to this research during the present year has been applied to the permanent plant, $8,200 has been expended in salaries, and the balance for running expenses of the laboratory and the director's visit to some of the leading laboratories of Europe.

The scope of the plant and its expected usefulness were described at some length from the plans in my previous report, and these plans have been followed with but little deviation.

THE POWER PLANT.

We have installed during the year as a part of the power plant and workshop:

(1) An alternating current plant of about 30 horsepower, suitable for the generation of current for high temperatures, and an autotransformer in which a very wide range of regulation is provided for.
(2) A 15-horsepower electrically-driven air-compressor capable of delivering air or some other gas to the laboratory room under a pressure of 500 pounds.
(3) An electrically-driven vacuum-pump for exhausting reasonably large spaces rapidly.
(4) A small blast-motor for delivering large volumes of air to the gas-furnaces under a pressure of about 10 pounds.
(5) A powerful vertical drill-press for the workshop.

Basement space was furnished by the Survey during the past winter for mounting the heavy machines. Suitable connections leading to the laboratory had been provided at the close of the previous year.

NEW LABORATORY EQUIPMENT.

New apparatus has also been mounted in the laboratory, as follows:

(1) A gas thermometer for an original determination of the fundamental scale of temperature above the existing scale, which extends only to 1150° C. Almost all the temperatures used in mineral work lie above this limit.
(2) Several resistance furnaces arranged for melting minerals under conditions which not only admit of temperature measurements, but of the control of the atmosphere and its pressure during melting or solidification.
(3) A resistance furnace for use with the gas thermometer, in which especially exact control of the conditions of measurement is provided for.

(4) A large gas-tight bomb for use as a Moissan arc furnace or with carbon resistances, in which a gas pressure of 500 pounds can be maintained with temperatures as high as 2500° C.
(5) An iridium resistance furnace of the Nernst type, intended for heating small quantities of mineral to 2100° without the pressure of disturbing carbon products.
(6) A screw compressor for hand power, with about 1 cubic foot of working space and a maximum working pressure of 85 tons.
(7) An outfit of platinum ware for the chemical section.

In addition to the above, a hydraulic press, with a suitable gage for pressure measurement, has been ordered in Germany, to be modeled after the one which has been so successfully used by Professor Tammann in Göttingen, which is expected to reach the highest hydraulic pressures obtainable—upward of 3,000 atmospheres—but it has not yet been delivered.

Much of this apparatus has been designed and built in our own shop, after some disappointing experience with outside contracts. The shop equipment, which was described in some detail in my last report, has been put to a severe test by these emergencies and has met the demand upon it most satisfactorily.

The laboratory equipment as it now stands is more intelligibly classified in this way:

(1) Gas furnaces for the preparation of specimens.
(2) Furnaces reaching 1600° C., with facilities for the accurate measurement of temperature and for work in oxidizing or reducing atmospheres or vacuum.
(3) A furnace reaching 2100° C. in oxidizing or reducing atmosphere in which temperature can be measured.
(4) A large furnace containing electrodes for arc or carbon resistance heating on a considerable scale and with any pressure up to 500 pounds or a vacuum.
(5) A pressure plant for supplying gas at 500 pounds.
(6) A pressure plant (Barus) reaching 2000 atmospheres water pressure in a very limited space, equipped with pressure gages.
(7) A water-pressure plant (Tammann) to reach the highest pressure with greater convenience and certainty; also with gage. (Under construction.)
(8) Arrangements for heating all the above with electricity except (1).
(9) Complete equipment for the measurement of temperature and for standardizing same.
(10) A good shop equipment, both for new construction and repairs.

SCIENTIFIC WORK OF THE YEAR.

The scientific work of the year, while the pressure plant was being installed, has been necessarily confined to the study of mineral combinations under atmospheric pressure.

Feldspars.—The investigation of the lime-soda feldspar group which was begun in the Geological Survey has been finished, after nearly three years' work upon it. The investigation has shown that the lime-soda feldspars form a continuous series of mixed crystals capable

of stable existence in any proportion of the two component minerals. The proof of isomorphism depends upon two facts which we were able to establish experimentally: First, a continuous change in the temperature of melting corresponding point for point with the change in percentage of the two components; second, upon the continuous change in the specific gravity with the chemical composition in the same way. We were able to prepare artificially all the feldspars which were investigated, in high chemical purity, according to the strictest standards of quantitative chemistry. They were also studied optically and identified with established natural types. The chemical purity of the specimens is responsible for a large measure of the success of the investigation, for thermal measurements, even when carefully made, have but little significance if disturbing subordinate reactions are present. For the same reason good specific-gravity determinations are possible only in chemically pure and homogeneous material.

As the percentage of the more alkaline feldspar in these mixtures increases, the viscosity of the molten mineral comes to be of the same order of magnitude as the rigidity of the solid crystals. This gives rise to an entirely new phenomenon, both to physicists and mineralogists. It becomes possible to superheat the crystals 150° or more above the point where melting begins, on account of the mechanical resistance to molecular deorientation which is offered by the hyperviscous liquid.

The investigation contributed not only a number of positive conclusions on the subject of rock formation, but also a valuable verification of the theory of isomorphism which had been developed by Professor Roozeboom, but which had never been put to a fair test over a long range of temperature.

Incidental to the investigation, it was found that considerable viscosity in liquid minerals means considerable undercooling before solidification occurs, unless some powerful outside agent can be brought in to restore the equilibrium—a fact which makes it dangerous to draw far-reaching conclusions from observations of solidifying temperatures, but which clearly shows the possibility of feldspar formation far below the melting temperatures of these minerals. A liquid feldspar magma of any composition, if cooled rapidly, usually does not solidify at any particular point, and may become mechanically solid without crystallization at all—that is, it may form a glass. Some study of glass formation is almost inseparable from any thermal investigation of rock-forming minerals.

The measurements contained in this investigation do not depend upon the personal judgment of the observer; that is to say, instead of merely watching a particular mixture until it appeared to melt and then recording the temperature, some physical phenomenon which gave a positive record, like the absorption of heat in melting or the release of heat in solidification, was always measured. In this way the personal judgment of a particular observer does not enter into the interpretation of the results.

A number of technical details and conclusions of interest to specialists were also established, but will not require recounting here.

A special grant of $1,500 was made by the Institution in February, 1905, for the publication of this paper, with suitable illustrations. It was carried through the press and issued during the summer as publication No. 31 of the Carnegie Institution of Washington.* An extract from the paper, under the same title, was printed in English in the American Journal of Science in February, 1905. A second extract in German for the Zeitschrift für Physikalische Chemie is now in press.

Pyroxenes.—Upon completion of the experimental work of the feldspar investigation the laboratory entered upon the preliminary work of a second investigation of the same general character upon certain minerals of the pyroxene group. This group of minerals is perhaps second to the feldspars in importance as a component of the earth's crust, but on account of the wide range of chemical compositions which it includes is a difficult and very comprehensive investigation. The first step in the study was, as before, the preparation of chemically pure and well-identified component minerals. The first one to be chosen was the mineral wollastonite, a simple calcium silicate.

It has been the uniform experience of experimenters heretofore that when chemicals were mixed in the proper proportions for wollastonite, and melted, the crystalline product did not prove to be wollastonite, but a mineral which does not exist in nature at all. It was therefore determined to investigate the reasons for this and to establish the necessary conditions for the formation of a true wollastonite, if one could be made. This has now been successfully accomplished, and we now know that the deciding factor is the temperature at which crystallization occurs; that when the mineral forms above this temperature the pseudo-form appears and is stable, and when forma-

* The Isomorphism and Thermal Properties of the Feldspars. Part I, Thermal Study, by Arthur D Day and E. T. Allen. Part II, Optical Study, by J. P. Iddings. (With an introduction by George F. Becker.) Octavo, 95 pages, 25 text figures, 26 plates.

tion occurs below this temperature the true wollastonite found everywhere in nature is reproduced. Furthermore, if crystallization occurs at higher temperatures and the silicate appears in the pseudo form, upon cooling down again it goes over into true wollastonite below this inversion temperature under favorable conditions. This offers rather striking incidental evidence of the formation temperature of portions of the earth's crust. The appearance of one form of mineral at certain high temperatures and of another form at lower temperatures without change in the chemical composition, together with the fact that only the lower form is found in natural rocks, leads at once to the conclusion that portions, at least, of the rock formations in which this mineral occurs must have solidified at temperatures below this limit.

In the study of the feldspars we were able to show that the particular formation known to the mineralogist as the zonal structure can only occur between certain definite limits of temperature. Thus we have twice obtained trustworthy evidence of the temperatures of natural rock formation.

The work on wollastonite is practically finished and will be ready for publication during the present year.

While the component wollastonite was being studied work was also begun on ferrous silicate, another essential component of the pyroxene group and one which has proved very difficult to manipulate, owing to its excessive oxidation. This mineral has never been successfully prepared in any high degree of purity, and the problem therefore necessarily involves the development of new chemical processes for the preparation of ferrous carbonate as well as the determination of the conditions of equilibrium between ferrous carbonate, ferrous oxide, and the oxides of carbon for the range of temperature involved—a problem which has a direct bearing on the terrestrial conditions of formation. Furthermore, in so far as the chemical processes involve the reduction of common ferric oxide to ferrous oxide and metallic iron, reactions of vital interest to metallurgists are involved, which are important enough to carry through very carefully and to incorporate in an independent publication.

As these two efforts to produce the necessary components of the pyroxenes in sufficient purity have progressed, a good deal of work of a preliminary character has been done upon some simple combinations of lime and silica and of magnesia and silica, in so far as these are within the reach of that portion of the plant which is in operation. It will hardly be wise to offer premature conclusions upon this work, but the progress which has been made allows us to

anticipate positive results, and so far no insurmountable difficulties have been met with, nor has it been necessary for us to diminish the standard of accuracy which has heretofore been maintained.

It is interesting to note the continual cropping out of technical problems at every stage of the process. The development of a pure ferrous silicate has already been shown to involve the relation of pure iron to its oxides and to reducing agents, while the study of lime-silica mixtures is fundamental in the preparation of Portland cement. Questions of technical interest in glass manufacture reappear everywhere in handling silicate solutions.

The laboratory has also another matter in hand upon which work has been done at odd moments, but which is not yet far advanced, viz, the study of change of volume of crystalline substances when passing their melting-point—a question upon which positive experimental evidence has only once been obtained. Some fifteen years ago Professor Barus reached the conclusion, in his work upon natural diabase, that the mineral in its solid state was about 3 per cent more dense than the liquid at the melting temperature; but there is still some question as to whether this result may not have been influenced by undercooling during solidification.

VISIT TO EUROPEAN LABORATORIES.

Under an allotment of $600, payable from the present appropriation and authorized in February last, Dr. Day visited the laboratories of Europe in which mineral mixtures have been studied, during the months of May, June, and July just past. The objects of the trip were two: First, to gather technical information which might be of service in the equipment of the laboratory or in carrying out measurements of the high order of accuracy which we have adopted for this work; second, in the interest of progress in this general field, to arrange, in so far as might prove feasible, to divide the efforts of those engaged in this work, so as to avoid duplication.

The fundamental reason for the trip was an economic one. It is very desirable to avoid unnecessary or unsuccessful experiments at high temperatures whenever it is possible to do so, on account of the waste of resources involved, and of course equally undesirable that two or three laboratories should go over practically the same ground.

A great deal of technical information upon special points was obtained, which was most cheerfully given and will be of considerable benefit in the work of the coming year. It also proved possible to arrange for a moderate amount of coöperation with other scientists,

which will have the effect of covering a maximum amount of territory without undue overlapping.

So far as learned, this is the only laboratory anywhere in which the same order of accuracy that is expected in more strictly physical investigations has been attained in the study of mineral solutions. At the time when this standard was set grave doubts were entertained as to the feasibility of handling physical phenomena at high temperatures with anything like the certainty attained at ordinary temperatures, but the experience of this first year has justified the effort, and this standard will not be modified in any particular at present.

INVESTIGATIONS ON FLOW OF ROCKS.

Frank D. Adams, McGill University, Montreal, Canada. Grant No. 227. (For previous reports see Year Book No. 2, p. xxxiv, and Year Book No. 3, p. 119.) $1,500.

During the past year the investigation of the cubic compressibility of rocks has been completed and the results are now ready to send to Washington for publication by the Carnegie Institution.

In this investigation Young's modulus and Poisson's ratio were determined by direct measurements on short columns of the rocks selected, which were submitted to stresses in a 100-ton Buckton testing-machine. From these values that for the cubic compressibility of the rock and also the modulus of shear were calculated. The rocks selected for measurement, 16 in number, were typical representatives of the acid and basic plutonic intrusives, together with certain marbles. These rocks, being massive and isotropic, fulfilled the conditions required for accurate measurement by the method employed, while at the same time the plutonic intrusions represent, so far as our knowledge goes, the rocks constituting the mass of the earth's crust. An investigation into the elastic constants of plate glass was also made for purposes of comparison with the results obtained in the case of rocks.

These determinations will afford data for the mathematical treatment of a number of great problems in geophysics.

The investigation of the flow of rocks has also been continued. The methods formerly applied to the study of the flow of marble have been extended to various impure limestones, dolomites, etc., such as the lithographic limestone of Bavaria (Solenhofen limestone), the black Belgian marble, and the dolomites of Cockeysville, Maryland, and of Lee, Massachusetts.

In the case of these harder rocks the aim of the investigation was to determine not only the nature and extent of the movements induced by pressure, but also to measure the strength of the rock before and after deformation. Curiously enough, while this measure of relative strength can be made in the case of marble, it has been found impossible, so far, to determine it in the case of the rocks in question, owing to the fact that upon the removal of the steel which surrounds the rock during the deformation the relief of pressure develops cracks which run through the rock in certain directions.

The nature and mechanism of the flow developed in the rocks have, however, been determined. A series of experiments have also been carried out to ascertain whether after the deformation of the marble in the cold the rock will recover its strength on resting or by heating, as in the case of steel.

An investigation into the nature of the deformation suffered by crystals of various rock-making minerals when submitted to pressure, after having been embedded in fused alum, fusible metal, sulphur, and other solids, and then inclosed in strong tubes of copper, has been carried out and is nearly completed.

A series of experiments has also been carried on with a view to measuring the force required to deform standard columns of different rocks under identical conditions of plastic flow, and thus to measure the relative plasticity of these several rocks when they are caused to move by stress in the earth's crust.

During the past summer apparatus has been constructed and material prepared for the completion of these several investigations, and for the extension of the work during the coming year to the harder crystalline rocks, such as granite and diabase.

Bibliography of Geophysics.—For report on this subject, see under Bibliography, page 86.

HISTORICAL RESEARCH.*

BY A. C. McLAUGHLIN, DIRECTOR OF THE DEPARTMENT.

I. The work of the Bureau of Historical Research during the past year has been developed along the lines marked out in the report for 1904. A number of the tasks then under way have not as yet been completed, and they are so far-reaching in extent and character that they can not soon be finished. The early part of 1904 Prof. Charles M. Andrews, of Bryn Mawr, began an examination of the sources of American history in English depositories. He worked at this task for several months without finishing the general survey which he was preparing. The work he was enabled to finish was, however, of great value, and he prepared a preliminary report which was in part read before the American Historical Association at the Chicago meeting, December, 1904, and was later printed in the American Historical Review.† For the completion of the undertaking Professor Andrews went again to England this past summer. The nature and importance of this enterprise is in some manner brought out by the opening paragraphs of this preliminary report:

Notwithstanding the fact that for a hundred and fifty years our colonies were a part of the British Empire, no systematic attempt has ever been made by British or American historians to discover the extent and value of the material contained in British archives relating to American history. Persistent and long search has frequently been made for documents bearing on a given subject or connected with the history of a given colony, but such investigation has usually been confined to well-known and fairly well arranged collections, examination of which was comparatively easy and a successful result highly probable. Outlying sources, records relating to other than colonial subjects, and groups containing only occasional and isolated documents have remained largely unexplored; while even such compact and clearly defined collections as the Colonial Office papers have never been thoroughly and critically examined.

The time was therefore opportune for a more thoroughly organized attack upon the British records, and for the discovery, as far as human imperfection would allow, of all documents that directly or indirectly bear upon our history. Tedious though the work promised to be, it seemed to be justified by the possibility of obtaining even an approximate description of each isolated document, important or unimportant, and of each collection, great or small, that might some time be needed for future writers of our history.

II. While this report on the materials in England has been in course of preparation, an effort has been made to examine such transcripts from the English archives relating to American history as are

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* Grant No. 224. $14,000. (For first report see Year Book No. 3, pp 65–79.)

† "Materials in British Archives for American Colonial History," Am. Hist. Rev., Vol. X, No. 2.

to be found in this country. Little is known by historical workers concerning the great amount of materials that are here available; not even a general list of the important collections is in print, and thus it may easily happen that investigators go to England for their sources or send to England for copies when copies are at hand on this side of the water, where they can be easily and readily used. So much has been done by States and by historical societies to gather transcripts of papers bearing on colonial history that a general guide to such materials is needed. Moreover, without some general guide the different States or local societies are in danger of incurring unnecessary expense by copying materials already available. It may reasonably be expected that this report on the transcripts in this country will prevent the needless duplication of work. The task of gathering full information about these transcripts has proved a large undertaking. Mr. W. G. Leland spent several months in Virginia, North Carolina, and South Carolina in listing and calendaring those papers, and in doing other tasks for the bureau to which reference is made in the succeeding paragraphs of this report. This work is still in progress, but we may expect that before many months the bureau will have in readiness for the printer a comprehensive report on the sources for American history in British archives. The first part of this report will, it is thought, be the work of Professor Andrews, a general description of the English archives and a guide to the American materials to be found there; the second portion will give a list, possibly a full calendared list, of the copies in this country from British archives; the third will give reference to printed copies of like materials. I can only say that some such guide will be of immense service to the investigators of the future; it will be likely to lessen the labors of scholars for generations to come, and is one of those undertakings of general usefulness for the advancement of historical science which seem natural to suit the purposes and activities of this bureau.

III. During the past year considerable attention has been given to discovering and copying official letters from the delegates in the Continental Congresses and the Congress of the Confederation. Much as has been written on the Revolution and the early history of the United States, many of the most important records have not been accessible to the investigator. The papers of the old Congresses are now being printed—most of them for the first time—by the Library of Congress. It is highly desirable that, in addition to the reports and journals, there should also be published the letters sent by the delegates to their home governments. The work of

looking through the papers in the State archives to discover these letters is of course arduous and time-consuming. Thus far (October, 1905) we have examined thoroughly only the archives of Virginia, North Carolina, and South Carolina. The letters found there have been carefully copied. A few have, by diligent inquiry, been found in private hands and copies have been made of them. It is certain that such materials must be hunted out and published some time, and in consequence, though the job is long and not an easy one, it is best to begin it and to carry it forward in connection with the work of calendaring the transcripts from British archives.

IV. Another task, in some ways even greater than those already reported on, is that of gathering general information concerning manuscript sources of American history. Such manuscript sources as are in this country are of course widely scattered and will remain so; but their extent, character, and location should, it seems, be known to American historical scholars, or at least the investigator should be able to turn to one central place of information to learn of the whereabouts of manuscripts that he may desire to use. It seemed well to begin the gathering of information by examining the collections of historical societies. Something has been done in this direction and considerable information has been gathered concerning private collections, especially in the Southern States.

V. Prof. W. R. Shepherd, of Columbia University, spent the summer in Spain preparing a report on the materials in Spanish archives relating to American history. For this task Dr. Shepherd was well prepared, inasmuch as he had already spent a year working in these archives and had made a number of important discoveries. It is now difficult to say whether, as the result of one summer's work, he will be able to complete a general survey of the whole field; probably another special examination will be necessary for at least the period before 1550.

VI. Mr. Luis M. Pérez has been engaged for about four months in preparing a report on the archives of Cuba. The materials have been fully gathered and in the course of the winter the report will be put into final form.

VII. An examination has been made of the Schoolcraft papers in the Smithsonian Institution and the Library of Congress. This work has been done by Mr. J. H. Russell, Mr. E. D. Lewis, and Mr. J. S. Fox, each of whom was busy several weeks. The two collections are large and have up to the present been practically unknown to historical investigators. The papers, while well cared for, have not been in a condition for use, being unarranged and unlisted. They

have proved to be valuable for historical purposes. Schoolcraft's long residence on the frontier, his study of ethnography, and his extended acquaintance with public men account for the value of his correspondence to investigators, especially to those interested in western history. The collections are of chief significance for Michigan history, and an arrangement has been made with the Michigan Pioneer and Historical Society to print at least all the important materials relating to the history of the State, if not all of the materials of historical interest. This publication will make a fresh and helpful contribution to the available sources for the history of the West and will have in many cases more than merely local interest. It may be said that the careful examination of such collections as the Schoolcraft papers seems to be a desirable activity for the bureau, even if the publication of the papers is not undertaken, because it is of service to know what they contain and whether they should be used by persons engaged in particular problems of research.

VIII. When the report of the bureau was made, in 1904, work of examining the diplomatic archives of the Department of State was well under way. This task, which consumed several months of time, and of course could not by any means exhaust the resources of the Department, was not finished until December (1904). The purpose was to discover the extent of the diplomatic correspondence from 1789 to 1840, to ascertain with some approach to exactness the amount printed in the American State Papers, and to get a clear idea of the character of the documents and their usefulness for historical research. While it was well known that they contained a vast amount of material unknown and unused by historical workers, no one could form without such an examination a very adequate notion of how large a proportion was of more than mere administrative interest. A paper on the "Diplomatic Archives of the Department of State" was read by the director of the bureau before the American Historical Association at the Chicago meeting (December, 1904) and a more extended paper was printed by this Institution.* Acting on the suggestion of the bureau, the Secretary of State asked Congress for a small appropriation to begin copying these documents for publication, and an effort was made to induce Congress to pass such an appropriation. Efforts to this end, however, were fruitless, although it may well be hoped that at no distant day Congress may see the usefulness of having these papers in print, so that they may be easily used, not alone by writers of history, but

*The Diplomatic Archives of the Department of State, 1789–1840. Publication No. 22. Washington, 1904.

by statesmen and public men and other persons interested in the diplomatic career of the United States. The work of the bureau has enabled one to speak with a considerable assurance concerning the amount of material and the expense of transcription, for the estimated number of words was not a mere guess made after a casual examination, but a real estimate made after months of work, during which a large majority of the volumes were handled and their pages turned. While, therefore, in the end the estimate is only an estimate and may be far from absolute accuracy, it is one based on patient and laborious examination. A considerable portion of this work was done by Mr. James Herbert Russell, of this bureau. It should be said that the officials of the State Department are in sympathy with this work and desire to have these valuable records printed. Special thanks are due to Mr. Andrew Hussey Allen, of the Bureau of Rolls and Library, and to Mr. Pendleton King, of the Bureau of Index and Archives, who took active interest and in every way gave facility for the work of examination.

IX. Attention was called in the last report to the task of preparing a bibliography of the writings on American history for 1903. It was then hoped that the list would soon be published, but a number of unavoidable delays necessitated the postponement of publication. The volume has, however, at last appeared. The task of deciding on method of classification and on the forms of entry and other problems of this sort incident to the first publication of a book of this character are in part responsible for the delay. Most of the labor was done, under the general guidance of the director, by Mr. William Adams Slade and Miss Laura Thompson, of the Library of Congress, and Mr. Ernest D. Lewis, of the bureau. It is perhaps unnecessary in this report to enlarge on the value and the usefulness of this publication, which I believe should be continued from year to year. No other agency can do the work so well as the Carnegie Institution of Washington. It is one of those undertakings that, having no commercial basis and being of general interest to the profession, naturally fall to the Institution; it will be of continuing use to all students and investigators in American history as well as to librarians; it will do for investigators throughout the country what many are seeking without satisfactory advantages to do for themselves, in order that they may not fall hopelessly behind in their knowledge of the bibliography of their subject. The natural sciences are adequately cared for in the great international series, while most fields of historical bibliography are neglected; and yet historical science, without other appliances or materials with which to work, is

peculiarly dependent on print and publication. My strong desire to see such a series of publications is based in part on my experience as managing editor of the American Historical Review, where I found the hopelessness of trying to call the attention of the historians of the land to one tithe of the materials that in one form or another were issuing from the press.

X. To the examination of the archives of the Government there is no end. The Guide to the Archives, which was published by the bureau in 1904, has proved to be of great service to investigators. Such a book, however, needs occasional revision, and many of the collections which it mentions require particular attention. With this end in view considerable work has been done during the year. Portions of the Guide dealing with the Pension Office have been carefully revised; certain collections have been examined in the Library of Congress and the State Department. Such work, without showing immediate results of much significance, is necessary, if the bureau is to act satisfactorily as a guide to investigators who come to Washington to carry on their researches.

XI. In some instances assistance has been given by correspondence to investigators who desired reports on materials for their work. In other cases persons coming to Washington have received attention and been aided in getting access to materials they sought. This portion of the bureau's work is not unlikely to be of continuing and growing value and to justify the establishment of such an agency for the aid of historical investigators. Not to mention persons who have come to Washington for only a day or two in search of particular material, a number coming for continuous investigation of some weeks have been given assistance in one form or another that has seemed to be of service: Miss Grace E. Burroughs in her work on Educated Slaves, Mr. William O. Scroggs in his work on Walker's Career in Nicaragua, Mr. Charles Meyerholz in his work on Federal Control of the Territories, Dr. I. J. Cox in his work on the History of the Southwest.

XII. With the preparation of this report the work of the bureau passes to my successor, Dr. J. Franklin Jameson, who was chosen to succeed me on October 1, 1905. I need hardly say that the task of organizing the bureau has been of immense interest, and I think that its value to historical scholars has been demonstrated. In my successor the Institution has secured the services of a scholar of wide reputation who is admirably equipped for the duties of the position. I surrender the work with some personal regret, but with assurance of the continued growth and increasing usefulness of the bureau.

Haskins, Charles H., Harvard University, Cambridge, Massachusetts. Grant No. 291. *Study of the documentary materials for Anglo-Norman history.* $1,000.

As this grant was made in May, 1905, no regular report can yet be made. Professor Haskins spent the month of July in preliminary work in the archives and libraries of Normandy and Paris, and has also begun a systematic exploration of the printed material.

Phillips, Ulrich B., University of Wisconsin, Madison, Wisconsin. Grant No. 289. *Study of the economic, social, and political phases of the plantation system in the ante-bellum South.* (Continuation of Grant No. 193.) $300.

Dr. Phillips has carried on his researches in the various collections at Madison, and at Louisville, Kentucky; Atlanta, Athens, Savannah, and Milledgeville, Georgia; Columbia and Charleston, South Carolina, and at several intermediate points in the South. This work is largely with original documentary material of which little is indexed or organized in any way, and as the field of interest is a great and complex one, the policy of carrying along several lines of inquiry at the same time has been pursued. By this means it is hoped to secure in notes or copied documents the whole body of significant items for a study in the manuscripts, pamphlets, newspaper files, etc., through which it is necessary to go. The chief subjects of inquiry have been: The plantation system, the fluctuations of slave prices and the economic phases of slave labor, the Southern Federalists and the Southern Whigs and their relation to the plantation interest, and incidentally the career of William H. Crawford. Dr. Phillips has published during the year a preliminary article upon the "Economic cost of slave-holding in the cotton belt" in the Political Science Quarterly, and has in preparation an article upon the growth of the plantation "black belts" and an article and a collection of documents on the course of William H. Crawford.

Scott, G. W., Washington, D. C. Grant No. 275. *Study of private claims against foreign nations to which the United States has been a party.* (Continuation of Grants Nos. 60 and 141.) $1,200.

The research on the subject of the law of private pecuniary claims against the state has been continuously prosecuted during the past year and has progressed as rapidly as could reasonably be expected under all the circumstances. The work of gathering data on the law of claims against the United States Federal and State governments was interrupted by a journey abroad to ascertain the bibli-

ography (statutes, codes, court decisions, etc.) of the subject in the leading European countries, in order that the necessary literature might be purchased and shipped to the Library of Congress for future study. For centuries the European countries have recognized a pecuniary responsibility to individuals for damages done.

The insight obtained into the continental law while abroad has been useful since returning in the study of our own somewhat crude and developing law of claims.

Before the mass of notes and gathered material can be correlated and put in final literary form, the study of the foreign law must be completed. It was hoped that the writing could have been begun and some portion of the work finished by this time; but the difficulties mentioned in previous reports have caused delay.

Wright, James M., Johns Hopkins University, Baltimore, Maryland. Grant No. 269. *Study of the history of the Bahama Islands since 1848 and a complete report of the contents of its public archives.* $250.

Abstract of Report.—The archives of the Bahamas are kept in the public offices at the capital of the colony. There is no public archivist nor any person to whom is committed the special duty of caring for them. The occupants of these offices thus become the natural custodians of the records and documents deposited in their respective departments.

Permission to examine the papers in any one of the offices is commonly granted by its custodian. But there are different regulations in the different offices. Access to them is readily allowed in all the offices except those of the governor and the colonial secretary, which contain official correspondence. In these the permission is difficult to obtain, only limited privileges are granted, and all information taken from them must be submitted to a censorship.

These archives nearly all belong to the nineteenth century. Only two of the offices contain documents extending far back into the eighteenth century, and among the rest two of the most important series of documents do not begin until 1829–1832. The absence of many is unaccounted for.

The materials for history existing here are thus seen to be limited to comparatively recent times. However, they are sufficient to invite research and to make possible a thorough understanding of the last three-quarters of the nineteenth century.

PALEONTOLOGY.

Case, Ermine C., State Normal School, Milwaukee, Wisconsin. Grant No. 242. *Completion of a monograph on the Pelycosaurian order of Permian reptiles.* (For first report see Year Book No. 2, p. xxxvii.) $800.

Report.—The completed monograph contains 286 pages, 33 plates, and 76 text-figures. Over 175 pen and wash drawings and diagrams have been used in the illustration of the material. The material studied is that of the Cope collection in the American Museum of Natural History in New York and the collection of the University of Chicago; also some types in the Marsh collection in the Museum of Yale University. In the pursuance of the work the author spent the summer of 1905 in New York at the American Museum of Natural History, and during the spring and fall made several trips to Chicago to study material there and to consult references in the library. A considerable quantity of the Chicago material was shipped to Milwaukee to be photographed and drawn under the oversight of the author.

The name of the monograph has been changed to "The Pelycosauria of North America." The taxonomy of the suborder has been cleared up and the classification placed on a basis of developmental features. The probable origin, the development, and the culmination of the suborder have been made out and the progressive changes in structure during the progress have been described and figured. One new family, two new subfamilies, one new genus, and five new species have been described. Several species described from fragmentary material have been shown to be synonyms. Nearly complete osteological descriptions of several genera have been given and a complete restoration of the long-spined form, *Dimetrodon*, has been worked out. The skull of the genus *Edaphosaurus* has been redescribed from the newly cleaned specimen and its probably ancestral relation to the Placodontia demonstrated. The geological and geographical relations of the suborder have been brought out and their possible continuance into the Triassic suggested. The Pelycosauria have been demonstrated to be a highly specialized, primitive side branch of the early Rhyncocephalia. *Bathygnathus borealis* has been shown to be a true pelycosaur and not a Triassic dinosaur, so the beds in the vicinity of New London, Prince Edward Island, are shown to be Permian, in consonance with the rest of the island, and not Triassic outliers, as the Canadian geologists have been compelled to suggest from the evidence of the supposed dinosaur.

Hay, O. P., American Museum of Natural History, New York, N. Y. Grant No. 118 (supplement). *Completion of a monograph on the fossil turtles of North America.* (For previous reports see Year Book No. 2, p. xxxvii, and Year Book No. 3, p. 122.) $1,800.

During the present year the monograph has been pressed forward with all possible diligence. Nearly 500 pages of manuscript have been written, about 400 drawings have been made, and over 100 photographs have been prepared. The large number of fossil turtles collected by the writer in the Bridger basin in 1903 have entailed a large amount of work in their preparation and determination, but they have added greatly to our knowledge. A considerable number of interesting forms have been collected during the past year by the exploring parties of the various museums, and it has been necessary to study and figure these. It is hoped that the work will be completed within the present year.

Wieland, G. R., Yale University, New Haven, Connecticut. Grant No. 243. *Researches on existing and fossil cycads.* (For previous reports see Year Book No. 2, p. xxxvii, and Year Book No. 3, p. 123.) $1,500.

Abstract of Report.—Dr. Wieland reports that his time has been mainly occupied in bringing to publication the first results of the cycad investigations in the form of a quarto volume on American fossil cycads (structure), and in the preliminary work for a second volume of equal, if not greater, extent on American fossil cycads (taxonomy).

Williston, S. W., University of Chicago, Chicago, Illinois. Grant No. 49. *Preparation of a monographic study of the North American extinct Mesozoic reptiles.* (For previous report see Year Book No. 2, p. xxxviii.) $800.

Abstract of Report.—Professor Williston reports that he has been engaged steadily in the study of North American plesiosaurs, but on account of its magnitude he can not state just when the work will be completed. About 75 plates and a large quantity of manuscript have been prepared. One month of the past year was spent at Yale University in the study of the material in the museum there, and some weeks in the collection of new material in Wyoming.

PHILOLOGY.

Flügel, Ewald, Stanford University, California. Grant No. 244. *Preparation of a lexicon to the works of Chaucer.* (For first report see Year Book No. 3, p. 96.) $7,500.

About two-thirds of the preparatory work may be regarded as completed. The work itself is divided into six groups.

(1) *Revision and completion of the collection of Chaucer's works.*—Dr. Wildhagen is revising the slips for the Canterbury Tales, as far as this remains to be done; The Summoner's Tale, The Franklin's Tale, and The Doctor's Tale. Dr. Flügel is carefully revising this work and that of his Stanford assistants. He has corrected Dr. Anderson's work on The Parson's Tale, and Herr Moll is revising the slips for Troilus and Cresside, Book II. The slips for the first book were revised by Prof. Einenkel and Dr. Flügel during the summer. Herr Bernhoff is writing the slips for the English Romaunt of the Rose. Miss Mason, of Berkeley, is finishing the slips for the Legend of Good Women.

(2) *Alphabetizing of the revised slips.*—All the revised slips which had been assorted into a "rough" alphabet by Miss Kimball at Palo Alto have been assorted into an exact alphabet by Mr. Pönitz and Dr. Wildhagen. The letter "T" is now in its final shape.

(3) *Copying for the collateral apparatus.*—A few Middle English texts and a good many Old French texts were "marked," and the words underlined are being copied by Mr. Tanneberger. He will put these slips, revised, into an exact alphabet.

(4) *Copying of Old French texts (unpublished) of authors known to Chaucer and influencing his work and his vocabulary.*—M. François Bruel, of the École des Chartes, is furnishing monthly what appear to be excellent manuscripts of G. de Maehault's Balades, Lays, and other poems. He will collate and copy later in the year the Old French Boece and Melibée.

(5) *Work at certain articles for the Dictionary in its final shape* has begun and Professor Einenkel of Halle is putting the slips for the prepositions and conjunctions in order, putting them into bundles, and writing definitions for the rubrics, etc.

(6) *The work of verification of the accuracy of the printed text* and the supplementary collation of unprinted texts has not yet been begun methodically in the English libraries because new passages are coming up every day which will make a verification necessary.

PHONETICS.

Scripture, E. W., Zurich, Switzerland. Grant No. 246. *Researches in experimental phonetics.* (For previous reports see Year Book No. 2, p. xl, and Year Book No. 3, p. 114.) $2,700.

Abstract of Report.—The manuscript of a volume on the "Study of speech vibrations" has been received. It contains an account of the methods of recording, tracing, measuring, and analyzing speech vibrations. Experiments on the diaphragms used for recording sound showed that they follow the air wave by bending concentrically, and that the formation of nodal lines is almost lacking. The special apparatus giving curves of speech of the highest accuracy is described in detail. It works automatically, so that whole speeches, requiring two or three months for tracing, can be obtained, after the apparatus is once started, by simply attending to it for a short time once every twelve hours. Such a tracing covers a strip of paper often a quarter of a mile long. The material furnished by these tracings is unique, no tracing of continuous speech having ever before been made for any language.

Illustrations of the work of the apparatus are given in a plate of curves from a speech by Dr. Depew and another from the Cock Robin record; in examples of various vowels in English and other languages, and in a number of curves of such phenomena as the vibration of a gong, the noise of two blocks struck together, of a conductor's whistle, of a locomotive whistle, of locomotive puffs, of tones from a trombone, of a chord from a piano, of a tone from a plucked string, of notes from an orchestra and a band, of yodeling, of whistling, etc. The two plates are used to illustrate the methods of reading phonetic results from the curves with the unaided eye.

The volume also describes the simpler methods of measurement by which information concerning the pitch of the voice at each instant, the duration of sounds, accent, etc., are ascertained. The methods are illustrated by various examples, among which are some interesting studies of the interjections spoken by Dr. Weir Mitchell, and of initial vowels by Dr. Depew.

Several chapters are devoted to the methods of analyzing vibrations. The Fourier analysis into a series of simple sinusoids is shown to be inapplicable to speech curves, because it does not provide for inharmonic components and for friction. A method is developed whereby one factor of friction can be considered and the inharmonics can be closely approximated.

The fundamental problem of the mechanism of the voice in producing vowels occupies an entire chapter. Professor Hermann's proof of the incorrectness of the Helmholtz overtone theory is confirmed, and the puff theory is adopted as the basis of a more complete one. Experiments are described with water resonators that produced tones like those of the vocal cavities, an apparatus having been constructed that produced all the vowel sounds instead of only one, two, or three, as before obtained.

The last chapter contains complete instructions, with two detailed examples, for the analysis of vowel waves. Appended to the book are the schedules to be used in analyses with 12, 24, 36, and 72 ordinates, the two latter having never before been published; those for 72 ordinates were the first time calculated and tested at a great expense of time.

Professor Scripture hopes to soon have another study in readiness containing detailed studies of several records. The manuscript is well advanced, but has to be constantly revised and extended, owing to the fact that the fundamental ideas concerning speech sounds have to be developed as the work progresses. A few isolated facts out of the results of these studies were given in the last report (Year Book of the Carnegie Institution of Washington, No. 3, p. 114); before final publication, however, it is necessary to reduce the entire lot to a consistent phonetic system, the results involving views of speech differing widely from the prevalent phonetic conceptions.

On the foundation of the general phenomena of vocal action as explained in the volume now in hand and the laws and facts concerning the individual sounds as developed in the study under way, it is possible to proceed to the problem with which the work originated, namely, the laws of verse. The problems and the lines of work have already been stated (Year Book No. 2, p. 243; No. 3, p. 114). Records of English, French, and German verse have been obtained and partly studied, and it is expected that the results will appear later. The proof of the incorrectness of the typographical view of modern verse, as consisting of sounds, syllables, and feet that can be divided from each other, is believed to be complete, and a psychological theory of verse—the centroid theory—is found to be reliable. The relations of melody, stress, and duration as factors of rhythm in the several languages will be considered.

PHYSICS.

Ames, Joseph S., Johns Hopkins University, Baltimore, Maryland. Grant No. 206. *Redetermination of standard wave-lengths by interference methods in order to correct Rowland's "standards."* $1,000.

Abstract of Report.—The fact that Rowland's standards of wave length were inaccurate was clearly proved some years ago—first, by Michelson; second, by Fabry and Perot. The source of the errors was shown by H. Kayser to be inherent in the "coincidence method" as used in grating measurements. It therefore became necessary to devise a method free from errors and to redetermine the standard wave-lengths. This was done to a certain extent by Fabry and Perot. The measurements are, however, of such importance that it is the opinion of all physicists that their work should be repeated in several laboratories.

Throughout the entire investigation my assistant was Dr. James Barnes, one of the foremost investigators in this field of work.

An interferometer was constructed along the general lines of Fabry and Perot's apparatus, but with several improvements. Measurements were first made by the visual method employed by Fabry and Perot, but later on experiments were made in the use of photography. These last were successful so far as they went, and if this year's work shows the accuracy of the method it will open up an entirely new field of research with interferometers. So far very few wave-lengths have been determined, and these agree, within the limits of experimental errors, with those obtained by Fabry and Perot.

The following results have been obtained, however: (1) The photographic method has been developed; (2) new forms of spectrum tubes have been studied, and the best one has been adopted for future use; (3) various effects which might influence the permanance of the type of radiation have been studied; (4) a most careful study of the theory and adjustments of the interferometer has been made.

It is planned to make a full study of the photographic method and final measurements of as many wave-lengths as possible.

Barnett, S. J., Tulane University, New Orleans, Louisiana. Grant No. 149. *For determining whether an electric intensity is developed in a dielectric moving at right angles to a magnetic field.* (For first report see Year Book No. 3, p. 124.) $250.

Abstract of Report.—For a number of reasons no experiments except a few of a preliminary character have been possible during the past year. Work will be carried on in the future at Tulane Univer-

sity. One paper has been published correcting a fundamental theoretical error in a paper on the subject by Dr. H. A. Wilson, of Trinity College, Cambridge.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 210. *Investigation of nucleation of the pure atmosphere.* $1,000.

The object primarily in view in this investigation was a continuous record of the nucleation of the atmosphere in a locality relatively free from the habitations of man, and therefore free from nucleations of local and artificial origin. This inquiry seemed well worth while, after it had been shown that the nucleation of the atmosphere, even above cities, obeys certain clear-cut laws, showing a marked tendency to reach an enormously developed and sharp maximum in December and a flat but very low minimum in June. Two series of observations were made with similar apparatus simultaneously at Providence and at Block Island. The two stations pass through practically the same meteorological variations of wind and weather, while Block Island is, in the winter at least, nearly free from local effect. The data found at each station prove that the tendency to pass through maxima in December, observed at Providence in 1902–1903 and 1903–1904, has again unmistakably asserted itself. Moreover, the observations at both stations developed a new and surprisingly pronounced maximum in February as the chief feature in the nucleations of the last winter. Predominating in each of the series of results over the earlier maximum, and holding for *different* bodies of air, the February maximum at least can not be of local origin; and it is thus in a measure probable that the December maximum also is due to non-local causes. But whether these are the aggregated effects of remote terrestrial sources, or whether they represent an actual invasion of the atmosphere on the part of some cosmic agency, remains to be seen.

The air treated in the experiments was continually approaching a state of purity so far as foreign admixtures are concerned. Hence the properties of dust-free air, or in practice of filtered air, became increasingly important.

The method employed by the author for the study of dust-free air is believed to be a new departure, inasmuch as all results are expressed in terms of the number of nuclei observed per cubic centimeter, so that the nucleations produced are the criteria throughout. To offer conditions sufficiently varied for the experimental work the nucleation of dust-free air was *coarsened* by ionizing it, either by the

X-rays or by a weak sample of radium acting through a sealed tube. It thus appears that the ions or fleeting nuclei resulting are also pronouncedly of all sizes within limits, and that the increment of nucleation between two definite degrees of exhaustion (*i. e.*, degrees of sudden cooling) above the fog limit, but not too far from it, is greater as the radiation applied from without is more intense. Virtually the gradation of particles is thus more fine-grained or more nearly continuous with the efficient nuclei lying within closer limits of size, as the ionization is more intense.

Throughout the whole research the important bearing of the solutional or water nucleus on the phenomena of condensation has been made manifest.

The final general result to be referred to here is the readiness with which nuclei are produced by the gamma rays, even after penetrating a centimeter or more of lead, together with the distinction which is thus drawn, experimentally, between these rays and the X-rays. The latter show small penetration, but are so phenomenally active in producing secondary radiation that to a wooden fog-chamber the distance effect for a radius of over 6 meters between bulb and fog-chamber is relatively negligible. The effect of the gamma rays, on the contrary, in spite of the remarkable penetration evidenced, for instance, by the nucleation produced, is nearly vanishing when tested by the same nucleation at a distance of but 50 cm. X-radiation, sufficiently intense to produce persistent nuclei, is accompanied by curiously outspoken distributions, which seem to show either that the nucleation originates in the walls of the vessel or that, in consequence of secondary radiation, the density of ionization near the walls is such as to promote rapid growth of nuclei in those parts to abnormal sizes. The nuclei in question are over 200 times more persistent than the ions, and if they decay by breaking into like fragments one may estimate that the former are 5 or 6 times larger in diameter than the latter. Persistent nuclei produced by the X-rays require but a vanishing pressure difference to induce condensation. They have, moreover, the property of increasing in number if left without interference for a short time after radiation ceases.

Burgess, Charles F., University of Wisconsin, Madison, Wisconsin. Grant No. 247. *Investigation of the properties of electrolytic iron and its alloys.* $2,500.

Abstract of Report.—The investigation was begun in February, 1905, and has been carried on continuously since that time. An outline of the plan which was laid out, and which has been adhered to as closely as possible, is as follows:

(1) Improvements upon the method of electrolytically refining iron and the construction of a plant for the continuous production of electrolytic iron in such quantities as might be necessary for the investigations here and to supply the needs of other investigators who wish to use this material.

(2) Accurate determination of the purity of the iron thus produced and the quantitative determination of the very small percentages of the accompanying impurities.

(3) Determination of the properties of the iron thus purified; such properties including the hardness, malleability, tensile strength, elastic limit, elongation, melting-point and other critical points, corrodibility, electrical and magnetic properties, etc.

(4) Review of the literature and compilation of a bibliography relating to work which has been done on the purification of iron.

(5) An investigation of the uses of electrolytic iron.

(6) Determination of the influence of various heat and mechanical treatments on the properties of pure iron.

(7) Determination of the influence of various single elements associated with iron.

Dr. Oliver P. Watts has been engaged to take direct charge of this work. He was able to devote only a portion of his time to the investigation from March 9 to June 1, but since then his entire time has been available for it.

A new plant has been erected, consisting of five 9-gallon stone electrolytic cells and one filtration and settling tank, circulation pumps, electrical fittings, storage battery, and instruments. This plant has been running continuously since June 15, and from that date to September 6 the total amount of refined iron taken from the tanks was 393 pounds. By the recent installation of a new storage battery the output of these tanks is considerably increased, so that 8 to 9 pounds will be produced daily.

The electrolytic iron which has been thus far made and which it is proposed to make during the coming year is to be used in supplying the material for our investigations and also, so far as possible, in complying with requests for this material from other investigators.

A continual operation of the plant has shown the possibility of producing electrolytic iron for refining at a cost well under one cent per pound, provided it be carried out on a large scale, as in copper refining.

It has been shown by our analyses and those made elsewhere that the iron has a purity comparable to that of the purest copper, gold, and silver which is obtainable commercially.

The analyses which have thus far been made may be summarized in the following table:

		Per cent.
Carbon	0.00221	to 0.0084.
Silicon	0.	to 0.0268.
Sulphur	0.	to 0.0008.

Phosphorus, arsenic, manganese, copper, nickel, cobalt, calcium, and magnesium absent.

Much time has been given to the problem of melting the iron without introducing impurities. This involved an extensive study of refractory materials and different methods of furnace construction. We have recently succeeded by means of a specially designed furnace in melting the iron contained in a graphite crucible lined with a magnesia cement. The following analyses show the impurities in the iron before and after melting:

	Iron from tanks.	Same iron melted.
	Per cent.	Per cent.
Carbon	Less than 0.01	Less than 0.01
Sulphur	.0008	.0021
Silicon	none	none
Phosphorus	none	none
Manganese	none	.0088

A preliminary study of electrolytic iron under various methods of treatment has been made by means of a microscope, and some interesting micro-photographs showing the structure of electrolytic iron are given in the full report. The production of iron alloys has only recently been taken up, and the results can not therefore be given in this report.

Campbell, William, Columbia University, New York, New York. Grant No. 179. *Study of the effect of heat treatment upon the microstructure and physical properties of steel and iron.* (For first report see Year Book No. 3, p 124.) $1,500.

Abstract of Report.—The research upon the "Heat treatment of some high carbon steels" has been continued by a microscopic examination of the series heated to given temperatures from 600° to 1200° C. In addition the structures of the steels when subjected to quenching have been examined. The main point of interest hinges upon the breaking down of the carbide of iron cementite into free iron ferrite and graphite in the neighborhood of 1000° C., and in the formation of white cast-iron around the grains of steel when the temperature approaches the melting-point.

Carhart, Henry S., University of Michigan, Ann Arbor, Michigan. Grant No. 157. *Preparation of material for standard cells, etc.* (For first report see Year Book No. 3, pages 124–126.) $500.

Abstract of Report.—Since the last report extensive changes have been made in the absolute electrodynamometer, which has been used for the absolute measurement of the electric current for the purpose of determining the electromotive force of the Weston normal cell. Serious trouble was occasioned by the unusual elastic fatigue of the particular phosphor-bronze wire employed to support the movable coil. This difficulty has been overcome by employing a longer wire, annealing it in an electric oven, and using a twist of 180° instead of 360°. A remeasurement of the coils was made as far as possible, and the results are very gratifying, because they show that no changes of any moment have taken place in the large stationary coil.

At a conference on electrical units and standards called by the Reichsanstalt to meet in Charlottenburg on October 23, 1905, the Weston normal cell was adopted as a standard in place of the Clark standard cell. It becomes, therefore, all the more important that the electromotive force of the Weston cell should be determined in absolute measure before the meeting of the International Commission late in the autumn of 1906. Results will be reported later on.

Child, Clement D., Colgate University, Hamilton, N. Y. Grant No. 187. *Investigation of ionization in the neighborhood of a mercury arc in a vacuum.* (For first report see Year Book No. 3, p. 126.) $50.

Abstract of Report.—The following facts have been brought out by this investigation in addition to those reported last year. The space in the tube connected with a mercury arc becomes highly conducting. A luminous space gradually spreads out from the arc, and the front of this region has the greatest luminosity and the highest conductivity. This conductivity is not due to ions coming from the arc, nor to rays sent out by it. It is probably not due to the high temperature of the gas. A probable explanation is that when ions recombine they are in a condition of unstable equilibrium, much like the atoms of radioactive matter, and often break up again. There is an E. M. F. between electrodes inserted in different parts of the tube, which is possibly due to the more rapid diffusion of the negative ions. Hope was expressed in the beginning of this work that the velocity of the ions in the arc could be determined by a method similar to that used in finding the velocity of ions drawn from a flame, but the method could not be used on account of the ionization in the neighborhood of the arc.

Coblentz, William W., Bureau of Standards, Washington, District of Columbia. Grant No. 198. *Continuation of investigation of infra-red absorption and emission spectra.* $1,000.

Report.—The experimental part of this work, which has occupied two years from June, 1903, was performed at the physical laboratory of Cornell University. The problem was to determine the effect of molecular weight upon absorption; also the effect of chemical structure, *i. e.*, the arrangement of the atoms in the molecule, and the effect produced by the substitution of a CH_3 or OH group of atoms. The problem is long and intricate and only a few of the main results obtained will be summarized here:

(1) The infra-red absorption spectra of some 135 compounds, mostly of hydrogen and carbon, have been investigated to 15μ, using a mirror-spectrometer, a rock-salt prism, and a Nichols radiometer. The compounds include solids, liquids, and gases.

(2) A comprehensive study of isometric compounds shows that the arrangement or bonding of the atoms in the molecule, *i. e.*, its structure, has a great influence upon the resulting absorption spectrum.

(3) The maxima of absorption do not shift with increase in molecular weight.

(4) A rise in temperature of 20° has no effect upon the transparency of the compound, nor upon the position of its maxima of absorption.

(5) Total absorption is not influenced by the size of the molecule, while compounds having sulphur or halogens are more transparent than those having H, O, OH, or N which they replaced.

(6) The spectra of groups of compounds are similar and are characteristic of the grouping adopted by chemists.

(7) Carbohydrates have a characteristic spectrum with well-defined absorption bands in the region of 0.85, 1.7, 3.4, 6.8, and 13.8μ. Certain bands are closely harmonic.

Infra-red emission spectra.—The investigation consisted of two parts, viz, emission spectra of metals or salts of the metals in the electric arc, at atmospheric pressure, and the emission spectra of gases in vacuum tubes.

Such an investigation is of twofold interest: (1) Previous experiments showed that there are strong emission lines just beyond the red, which became less intense farther toward the infra-red (1.2μ), and the question arose whether emission lines exist beyond this point; (2) theoretically, all the emission lines predicted by our spectral series formulæ end just beyond the red—about 2μ. These formulæ

are somewhat empirical, and any information relating to infra-red lines predicted by them will aid in establishing their validity.

In the present work the same apparatus was employed as in the investigation of absorption spectra. The salts of the alkali metals were examined in the carbon arc. An examination was also made of the arc between metal electrodes, but in neither case could emission lines be detected beyond 2 μ. This is caused in part by the radiation from the oxides, which is sufficiently intense to obliterate any weak lines if there be any in this region. The vacuum-tube radiation does not contain that of the oxides; hence was better adapted to this work. Since there is but little heat radiated from a vacuum tube, a very sensitive radiometer was necessary—in fact, the most sensitive one yet constructed.

The following gases and vapors were examined: CO, CO_2, NH_3, H, O, N, C_2H_5OH, and H_2O. In the preliminary work an emission band was found in common at 4.75 μ for all gases except H and water vapor. After eliminating all traces of CO_2 this band was not found in any gas except C_2H_5OH (vapor), CO_2, and CO. Since this band is more intense for CO than for CO_2, other conditions being equal, it is quite probable that it is due to CO.

Nitrogen has strong emission bands just beyond the red, but none of the gases show lines beyond 2 μ, except CO and CO_2, for the region of 4.75 μ. These emission bands were examined for constant current and varying pressure of the gas, and *vice versa*. The band at 4.75 μ behaves in an entirely different manner from all the rest. Its intensity increases with increasing pressure (for constant current), but never attains a maximum, becoming quite asymptotic at 5 to 6 mm. pressure. On the other hand, the other emission bands increase in intensity with increase in pressure, become a maximum at about 2 mm. pressure, then decrease in intensity with a further increase in pressure, which agrees with observations in the visible spectrum. All lines increase in intensity with increase in current, as found in the visible spectrum. The whole shows that the bands near the visible spectrum are related to those in the visible, while the 4.75 band is of an entirely different type.

The *decrease* in infra-red radiation and the simultaneous *increase* in the visible radiation, with *decrease* in *pressure*, explains the rise in efficiency of vacuum tubes observed by others.

The results of these investigations were published in October, 1905 as Publication No. 35 of the Carnegie Institution of Washington.

King, Arthur S., University of California, Berkeley, California. Grant No. 164. *Production and study of emission spectra at high temperatures.* $1,000.

Report.—During the past year Dr. King has been engaged in experiments extending and confirming the results noted in his first report; also in an investigation of the argon spectrum in vacuum tubes and in the preparation of the English edition of the "Atlas of emission spectra," by Hagenbach and Konen.

The further work with electric ovens at the University of Bonn showed the usefulness of the method in obtaining the spectra of a large number of substances through the agency of temperature alone, many differences being noted in these spectra as compared with those given by the flame, arc, and spark; the shift of maximum of radiation in the cæsium series with varying temperature was confirmed, and groups of bands discovered in the spectra of calcium, strontium, barium, and copper, which are not brought out by the usual methods. The applicability of the oven in the study of absorption spectra was also demonstrated. The work is being continued in the University of California with the entire apparatus inclosed in a vacuum chamber.

In the University of Berlin the conditions were investigated under which the very small quantity of argon in ordinary air can be made to show its spectrum. The results of other observers had shown quite unusual conditions to be required for the appearance of this spectrum. A series of experiments by the writer showed the necessary condition to be a very high momentary value of the current intensity, such as is given by the conditions of the oscillating discharge. When this condition was present, the argon spectrum appeared distinctly in vacuum tubes containing air at various pressures, and even in the open air with the spark between metallic electrodes.

Lewis, E. Percival, University of California, Berkeley, California. Grant No. 150. *Photographic investigations of vacuum-tube spectra of gases and vapors.* (For first report see Year Book No. 3, p. 128.) $500.

The large quartz prisms ordered by Professor Lewis from A. Jobin, Paris, were not furnished until March of the present year, on account of the difficulty of finding large specimens of quartz. During the summer the lenses and prisms in a spectrograph of rough construction were tested, in order to determine the best permanent form to adopt. After the completion of the plans a mechanic took charge of the construction, which is now well under way. The spectrograph will be the largest and most efficient of its kind yet constructed, and it is hoped that the next report will present a satisfactory account of research work accomplished by its aid.

Nichols, Edward L., Cornell University, Ithaca, New York. Grant No. 286. *Quantitative study of fluorescence and phosphorescence, especially at low temperatures.* $1,000.

Report.—While the investigation, carried on in coöperation with Prof. Ernest Merritt, is intended to include the general subject of luminescence, the experimental work completed during the current year has had to do with the luminescence of sidot blende, a phosphorescent zinc sulphide that seems especially well suited to bring out the relationships existing between different types of luminescence. This substance is rendered luminescent by all known exciting agents, such as light, the Roentgen rays, radium rays, and cathode rays. Quantitative measurements of the luminescence excited by Roentgen rays have been made and the photoluminescence of sidot blende during excitation and subsequently has been determined. The results of these measurements are described in a paper in the October number of the Physical Review. This paper is the fifth of the series of studies of luminescence, for the further prosecution of which this grant has been made, and it is proposed to incorporate the substance of these and of the subsequent papers of the series in a final report to the Carnegie Institution of Washington.

The papers of this series already published bear the following titles:

1. The phosphorescence and fluorescence of organic substances at low temperatures, Physical Review, vol. 18, p. 355.
2. A spectro-photometric study of fluorescent solutions belonging to Lommel's first class, Physical Review, vol. 18, p. 403.
3. On fluorescence spectra, Physical Review, vol. 19, p. 18.
4. The influence of light upon the absorption and electrical conductivity of fluorescent substances, Physical Review, vol. 19, p. 396.
5. The luminescence of sidot blendes, Physical Review, vol. 21, p. 247.

Experiments upon the influence of red and infra-red rays upon the luminescence of sidot blende are in progress and the results will form the subject of the sixth of our series of papers. Orders have been placed for special apparatus for the study of the cathodo-luminescence of various substances. Most of this apparatus has already been received, and it is proposed to begin this portion of the work immediately upon the completion of the experiments on the influence of the infra-red rays.

Whitehead, John B., Johns Hopkins University, Baltimore, Maryland. Grant No. 178. *Study of the magnetic effect of electric displacement.* (Continuation of Grant No. 59.) $1,200.

Abstract of Report.—Alternating displacement currents were set up in a cylinder of paraffin by means of an alternating electromotive force impressed on electrodes on the two faces of the cylinder. The cylinder was surrounded by a magnetic circuit of soft iron laminations which was wound with many turns of fine wire. If the displacement currents have a magnetic effect, an alternating electromotive force should be set up in the secondary winding. The calculation of the magnitude of the effect from Maxwell's equation necessitated a large size for the apparatus, a high value of the impressed electromotive force, and an instrument for measuring alternating currents of the order of magnitude 10^{-6} amperes. In the experiments these conditions were met and results in good agreement with the values as calculated from Maxwell's assumptions were obtained.

A method for observing the analogous electric effect of magnetic displacement has been suggested by Kolacek in discussing the writer's former work. The results indicate that the various factors and quantities involved can not be increased to values necessary to give results which may be observed by experimental methods now at our disposal.

Wood, Robert W., Johns Hopkins University, Baltimore, Md. Grant No. 248. *Researches on the theory of light.* (For previous reports see Year Book No. 2, p. xxxix, and Year Book No. 3, p. 128.) $1,000.

The fluorescence of sodium vapor and the resonance radiation of electrons.—The work begun on this subject two years ago has been continued, and the results have been published in the Philosophical Magazine for November.

The fluorescence spectrum of the vapor of metallic sodium has been photographed, the vapor being illuminated with highly homogeneous light of varying wave-length. It has been found that certain lines in the fluorescence spectrum are associated, indicating that the molecule contains a number of groups of electrons, the stimulation of any one of which by light of the same period as that of the electron sets the entire group in vibration, without, however, disturbing any of the other groups.

If the wave-length of the exciting light is gradually changed, the lines in the fluorescent spectrum appear to dance about with a rippling motion, an illusion due to their periodic disappearance and reappearance. Very remarkable changes in the distribution of intensity in the fluorescent spectrum have been observed to accompany changes in the wave-length of the exciting light.

The bright lines of the fluorescent spectrum coincide with dark lines of the absorption spectrum, but only a small percentage of the absorption lines are represented. The same has been found to hold true for the bright-line spectrum obtained when plane-polarized light is passed through the vapor in a magnetic field. (See paper on Magneto-Optics of Sodium Vapor.)

An emission of light of the same wave-length as the exciting light has been observed when the vapor was illuminated with sodium light. This phenomenon may be called resonance radiation, and very possibly differs from fluorescence. It has been repeatedly looked for, but never before observed. It is of considerable importance in connection with the theory of the mechanics of absorption.

The magneto-optics of sodium vapor and the rotatory dispersion formula.—The results of the inquiry into this subject were published in the Philosophical Magazine for October.

The formula given by Drude in his "Optics" for the magnetic rotatory dispersion has been proven by measuring the rotation of the vapor of metallic sodium, formed in exhausted tubes in a powerful magnetic field, and the fact has been established that the numerous absorption lines of the vapor in the red and green-blue region exercised powerful rotatory effects.

In this preliminary work glass tubes were used, which were exhausted and sealed off from the pump. It was subsequently found that the hydrogen liberated from the sodium interfered greatly with the rotatory effects, and in the subsequent work the tubes were kept in connection with the pump. The phenomena exhibited by the vapor are extremely beautiful and very easily shown.

The results obtained from measurements made with the micrometer are shown in the form of a curve, observed values being represented by circles. Values of the constants A and B in the formula were calculated from two observed values of δ, and the values of δ for various wave-lengths calculated. These calculated values are represented by crosses on the plate, and will be found to fall almost exactly on the experimental curve. The value of the constant B, which is associated with the absorption line D_2, was about double that of A, which belongs to D_1. Tables of rotations for various vapor densities were made, and the formula tested under various conditions. With various dense vapors the observed value of δ midway between D_1 and D_2 was usually larger than the calculated. Rotations as great as 1500° were observed.

A series of photographic records, taken collectively, exhibit the general form of the rotatory dispersion curve.

The bright-line rotation spectrum of absorbing vapors.—With the apparatus described in the previous section a very remarkable phenomenon appears when the vapor has considerable density. Light from the arc is passed through a nicol prism, the steel tube containing the sodium (which traverses the magnet), and a second nicol set for extinction. On exciting the magnet the system transmits light which the spectroscope shows to be made up of a multitude of fine lines in the red and blue-green region. Over a hundred lines can be counted in the red region of the spectrum formed and about the same number in the blue-green region. These lines have been photographed with a 14-foot concave grating and found to coincide with absorption lines, the significant fact being, however, that comparatively few of the absorption lines are represented in the rotation spectrum. Just why this is so is not apparent. The rotatory power of an electron is probably inversely proportional to its mass. The lighter the electron in proportion to its charge, the greater will be the perturbations in its orbit produced by the magnetic field. Possibly the absorption lines which exercise rotatory power result from the negative electrons of small mass, while the other absorption lines are due to heavier corpuscles, perhaps carrying positive charges.

The fact that the bright lines of the fluorescence spectrum appear to coincide with those of the magnetic rotation spectrum favors this hypothesis; for we should expect the lighter electrons to be set in more violent vibration by the light waves than the heavier ones. A further study of the phenomenon will doubtless throw more light on the subject. Iodine vapor also gives a very beautiful bright line spectrum.

Zahm, Albert F., Catholic University of America, Washington, District of Columbia. Grant No. 272. *Determination of resistance of air to moving bodies.* $1,000.

Abstract of Report.—Prof. Zahm reports that he has perfected a delicate balance for suspending bodies in the wind-tunnel, has measured the atmospheric resistance of a variety of spindle and hull shapes, particularly those of fair outlines, and has also measured the resistance of posts, rods, and wires, such as may be used for the bracing of structures and are to be exposed to the impact of the wind. He hopes to publish the results during the coming year.

PHYSIOLOGY.

Atwater, W. O., and **Benedict, Francis G.**, Wesleyan University, Middletown, Connecticut. Grant No. 258. *Investigations in nutrition.* (For previous reports see Year Book No. 2, p. xxxix and Year Book No. 3, p. 130.) $7,500.

Abstract of Report.—The experimental work has covered two general lines: (1) The more important experiments, in which the complete balance of income and outgo was determined and in which the subject spent the time inside the chamber; (2) nitrogen metabolism and digestion experiments following fasting.

The complete metabolism experiments were of two kinds: (1) Those in which the subjects fasted; (2) those in which the ingestion of food immediately followed a fast.

The determinations included all those pertaining to transformations of both matter and energy. The experimental technique has gradually developed to such an extent that during the later experiments it was possible to determine many more factors than during the earlier experiments. With regard to the measurements of heat, there were determined during fasting experiments the heat eliminated from the body of the subject and measured by the respiration calorimeter and the heat of oxidation of the solids in the urine.

The determinations involved in the computation of the balance of matter comprised (1) in the urine—weight, specific gravity, reaction, total nitrogen, creatinine, total sulphates, phosphoric acid, total sulphur, ash, chlorine, carbon, hydrogen (organic), and water: (2) in the respiratory gases, the amounts of water and carbon dioxide eliminated and the quantity of oxygen absorbed.

No satisfactory separation of feces was obtained in the fasting experiments. When food was ingested the determinations outlined above were supplemented by complete analyses of food, drink, and feces. These comprised determinations of water, nitrogen, fat, ash, carbon, hydrogen (organic), sulphur, phosphorus, chlorine, and heat of oxidation.

Other observations on the subject were an accurate determination of the variations in body weight, a series of thorough medical examinations by a medical practitioner, an anthropometric record, continuous observations of body temperature, pulse rate, and blood examinations, including a count of the red and white corpuscles, determination of the hæmoglobin and the microscopical examination of blood smears. In one instance a series of photographs of the subject was taken before and after a four-day fast.

Of especial interest is the nitrogen metabolism experiment, in which the total income and outgo of nitrogen was studied with great accuracy with the subject B. A. S. from March, 1905, until April 25, 1905. The period began with a fast of 7 days, then followed a period of 25 days with food, after which a 4-day fast was made, the experiment finally concluding with a 14-day period with food. This study is of unusual significance in that it showed the rate at which the nitrogenous material lost during fasting is regained by the body. During this period the food eaten by the subject was accurately sampled and analyzed and the nitrogen output in both feces and urine obtained. The series should prove one of the most interesting points in connection with the report.

Chittenden, Russell H., Yale University, New Haven, Connecticut. Grant No. 264. *Study of the minimal proteid requirement of high proteid animals.* (For previous report see Year Book No. 3, p. 131.) $2,500.

Report.—This grant is being used in studying the minimal proteid requirement of healthy dogs—as types of high proteid animals—sufficient to maintain the animals in a state of health, body weight, nitrogen equilibrium, etc. In the experiments so far conducted, dogs of different types have been employed, and the effects of a gradual diminution in the amount of proteid food, together with diminution in the amount of non-nitrogenous food, carefully noted.

Accurate analyses of food and excreta afford data for determining nitrogen balance, so that eventually reliable statistics will be obtained as to the actual amounts of nitrogen per kilo of body-weight and of total calories necessary for the maintenance of bodily vigor. In experiments of this kind the element of time is a very important one, and the real value and significance of the results can not be determined until many months have elapsed. The results so far obtained indicate that the experiments will possess considerable value as affording data of more than ordinary importance in the general subject of nutrition.

Mendel, Lafayette B., Sheffield Scientific School, Yale University, New Haven, Connecticut. Grant No. 265. *Study of the physiology of growth, especially in its chemical processes.* . $2,000.

Report.—The grant is being used in a study of the chemical composition of the developing animal body and the equipment of this organism for its nutrition, upon which growth essentially depends. Data are being collected at first hand regarding the composition of

various embryonic tissues at different stages of embryonic growth. For the nervous system a correlation between morphological and chemical development is already apparent. The chemistry of embryonic muscle is also already under investigation.

The purin content of the liver and muscles at various embryonic stages has been determined. The autolytic changes in these tissues are being investigated to ascertain the chemical organization of embryonic cells and the characteristics of purin metabolism. It is hoped later to include some investigation of the synthesis of purin compounds in the growing animal, and to ascertain whether the purin metabolism of the young is essentially different from that of the adult.

The occurrence of enzymes along the alimentary tract has also been investigated. For the sugar-inverting enzymes, in the case of the embryo pig, the data are ready for a preliminary report. A lactase is uniformly found in the embryo intestine and presumably a maltase, beginning with early embryonic life. Sucrase is apparently absent. This equipment, differing from that obtained in the adult intestine, bears an interesting relation to the peculiar diet (including milk sugar) of the young, in contrast with the adult, in which a sucrase is always present in abundance. These findings must be verified in other species when suitable material becomes available.

Finally, a study of the influence of various diets upon the proximate composition of the body has been begun. All the successful trials up to the present have been made with mice. The experiments are not yet sufficiently numerous to warrant permanent conclusions. One opinion may already be tentatively expressed, namely, that with diets rich in fat the percentage content of water in the body decreases, but the general make-up of the fat-free tissues is probably not essentially altered. It is hoped to extend these experiments considerably, and the entire investigation will be continued with the assistance of the as yet unexpended balance of the grant.

Osborne, Thomas B., Connecticut Agricultural Experiment Station, New Haven, Connecticut. Grants Nos. 192 and 263. *Application of methods already developed to a comparative study of the more important vegetable proteids.* (For first report see Year Book No. 3, p. 111.) $5,500.

Abstract of Reports, Grant No. 192 ($1,500).—Work under this grant was begun October 1, 1904, and Part I of the paper, giving the results of this investigation, has already been published in the American Journal of Physiology, vol. XIII, page 35, February, 1905, under

the title "The chemistry of the protein bodies of the wheat kernel; Part I, The protein soluble in alcohol and its glutaminic acid content."

The results were summarized as follows:

"In conclusion we here bring together the results of these determinations, that they may be more readily compared:

Percentage of glutaminic acid yielded by gliadin.

	Decomposed by—				
	HCl				H_2SO_4
Preparation	1	2	3	4	5
Per cent	37.00	37.33	34.2	35.50	25.3

"All these are minimal figures, since in each case some glutaminic acid still remained in the mother liquors, but we do not think that more than relatively insignificant quantities were lost, unless in the first separation from the mass of decomposition products. Respecting the amount which escaped separation from this solution we know absolutely nothing.

"From these results it would appear:

"(1) That Kutscher's determinations of glutaminic acid fall far short of the actual quantity of this substance yielded by the alcohol-soluble protein of wheat, and that they therefore afford no evidence which justifies the conclusion that this substance consists of two distinct protein bodies.

"(2) That fractional precipitations of this alcohol-soluble protein yield practically the same large proportion of glutaminic acid; so that, in view of their very close agreement in composition and properties, both physical and chemical, we have every reason to believe that only one such protein is present, for which we think the name gliadin should be retained.

"(3) That gliadin yields a remarkable proportion of glutaminic acid, much in excess of that from any other known protein and greater than that of any single decomposition product yet obtained in a pure state from any other true protein substance, the protamines, of course, excepted.

"(4) That this very large proportion of glutaminic acid in a food protein so extensively used is a matter of great importance in relation to the food value of this substance and deserves further careful study.

"The quantitative determination of the ultimate decomposition products of this alcohol-soluble protein is practically finished and the results of that work are nearly ready for publication. Large quantities of the other protein constituents of the wheat kernel have been made and it is expected that similar determinations of their decomposition products will be completed within a short time."

Grant No. 263 ($4,000).—Under this grant work has been in progress only a few months, and, as it has been impossible until recently to secure the full quota of assistants, the progress made has not been so great as it will be during the remainder of the year. A series of quantitative determinations of glutaminic acid has been made in over twenty of my pure preparations of as many different vegetable proteins, and the results of this work are practically ready for publication. The proportion of arginine, histidine, and lysine in several of these vegetable proteins has been determined, and it is my intention in the immediate future to make similar determinations in a large number of other proteins.

A great deal of time and labor has also been devoted to making large quantities of the purest possible preparations of the various vegetable proteins studied during the past years in this laboratory, with the intention of determining the proportion of the various decomposition products which they yield on boiling with strong acids. The purpose of this work is to obtain information respecting the structural differences between these various proteins, with a view to determine the chemical relations of these substances to one another, as well as their nutritive and physiological relations.

Reichert, Edward T., and **Brown, Amos P.,** University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 188. *Research on the crystallography of hæmoglobins.* (For first report see Year Book No. 3, p. 134.) $1,000.

Drs. Reichert and Brown state that their research has progressed satisfactorily. A report upon the result of their investigations may be expected later.

PSYCHOLOGY.

Farrar, Clarence B., Sheppard and Enoch Pratt Hospital, Towson, P. O., Maryland. Grant No. 163. *Experimental studies on structure and functions of the cerebral cortex, its histopathology and physiological psychology.* $1,000.

Abstract of Report.—The grant originally made for physiologic psychology was allowed to include studies on the cerebral cortex—its structures, functions, pathology. As a member of the staff of the Sheppard and Enoch Pratt Hospital, Dr. Farrar's work has included both clinical and laboratory studies, the latter dealing particularly with the normal and pathologic histology of the gray cortex. He has published articles on various phases of the subject, and there are also under way several other studies, both on developmenta and adult structure. These he hopes to have follow at intervals the preliminary paper on the "Growth of neurohistologic technique during the nineteenth century," which was published in the August and September numbers of the Review of Neurology and Psychiatry.

Franz, Shepherd I., McLean Hospital, Waverly, Massachusetts. Grant No. 80. *For investigation of the functions of the cerebrum with special reference to the functions of the associative areas.* $1,000.

Abstract of Report.—There has been a continuation of the work mentioned in previous reports: On the functions of the frontal lobes and on the functions of the temporal lobes. A number of negative results has retarded the publication of the work on the frontal region, but this part of the research is being vigorously pushed.

TERRESTRIAL MAGNETISM.

REPORT OF DEPARTMENT OF RESEARCH IN TERRESTRIAL MAGNETISM.*

BY L A BAUER, DIRECTOR.

The advances made during the previous fiscal year in the general discussion of the magnetic observations at present available for an analysis of the distribution of the earth's magnetic forces and of the secular changes laid bare the following fact

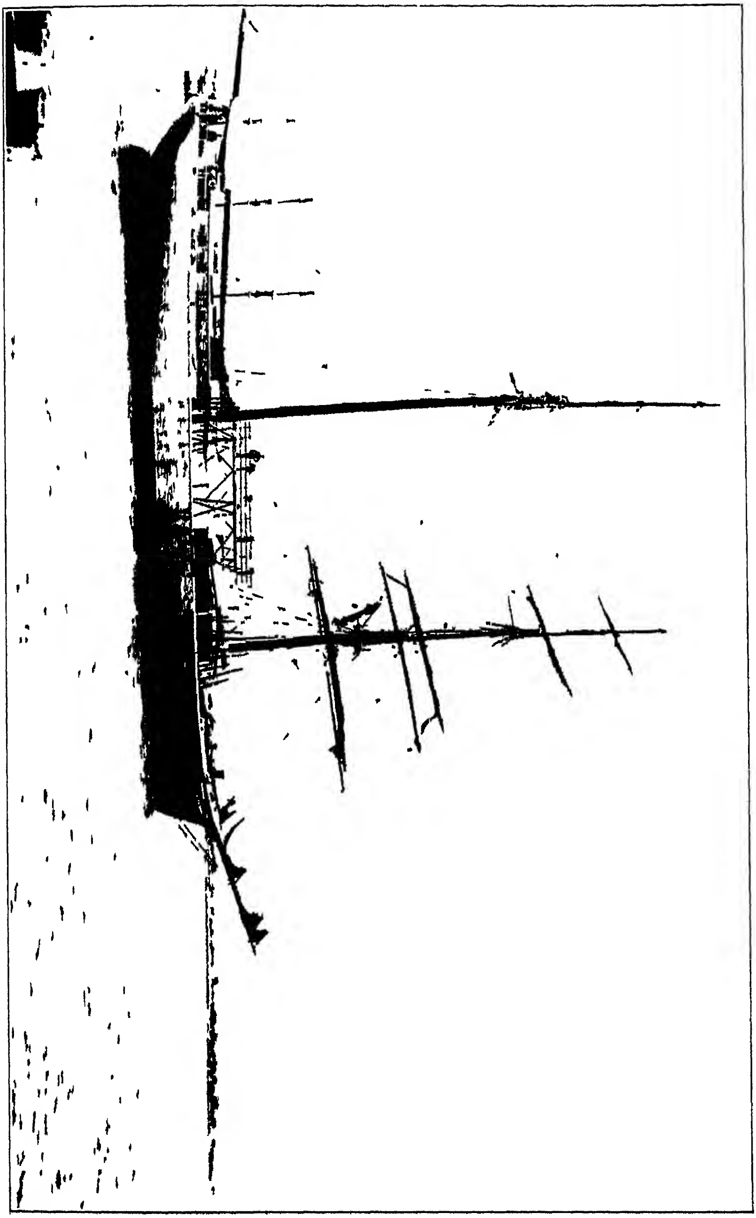
That until the present material, consisting, as it does, chiefly of observations made on land, and hence derived from only about one-third of the earth, is supplemented by careful and systematic observations over the oceanic areas, conclusions pertaining to the general magnetic conditions of the earth, no matter how skillfully they may have been derived or how plausible they may seem, can not demand entire credence nor be considered as unquestionably established.

Take for example the result obtained from the investigation of the secular changes in the earth's magnetism, based both on the existing observations and on the best magnetic maps published since 1840, "that the secular changes are caused not only by a shift in the direction or position of the earth's magnetic axis, but likewise by a shrinkage in the *intensity* of magnetization by an annual amount sufficiently large to be readily detectable in the short period of five years." If this conclusion be true it will constitute one of the most important of the many interesting facts concerning the earth's magnetism, and it will not be without its appropriate bearing on the physical history of our planet.

However, until the same analysis has been repeated with the aid of observations distributed over the greater part of the earth, no arguments in defense of the theoretical methods used in the analysis of the less comprehensive material will prevail against the io us and easily made criticism of "lack of sufficient data."

The same state of affairs obtains with regard to the existence or non-existence of electric currents, which are supposed to pass perpendicularly through the earth's surface, either coming from outside and entering the earth or coming from within and passing out into the air. The discussion of the data bearing on this question, as set forth in last year's report, would apparently decide in favor of the existence of such currents. But here again the criticism as to lack of data over the great regions embraced by the oceans prevails with full force.

*Grant No 233 $25,000 for maintenance for 1905. (For first report, see Year Book No. 3, pp. 68–74.)



THE "GALILEE" IN SAN DIEGO HARBOR CAL, AUGUST 22 1905

The special observing bridge built 15 feet above the deck is shown between the masts

Were it necessary, other examples might be cited to prove that our progress with regard to the great and principal facts of the earth's magnetism will be at a standstill unless a magnetic survey of the whole globe be undertaken immediately.

In consequence of these facts it has not been deemed wise to spend very much more effort in further elaboration of the discussion of the present data until some new and unquestioned material has been obtained.

With the approval, therefore, of the Executive Committee, it was decided to begin the observational work sooner than had originally been contemplated. On account of the large amount of field work undertaken and contemplated during the current year, the office work has necessarily not advanced as rapidly as in the previous year. Nevertheless, satisfactory progress has been made in certain directions, as related below.

OFFICE WORK PERFORMED.

INVESTIGATION I.—*Continuation* *secular varia-*
tion and compilation of data and *iblication on a*
comprehensive, uniform plan.—A pr ication of the
results of this investigation up to year was pub-
lished in the journal "Terrestrial M ospheric Elec-
tricity," December, 1904, under t s of magnetic
forces causing the secular variatio portion of the
earth's magnetism." The followi ised upon the
present material were reached:

(1) If we consider simply that p 's magnetism
which may be regarded as equival magnetization
about a diameter inclined approxim xis of rotation,
then it appears that this portion is subject to a secular variation arising from systems of magnetic or electric forces, two of which are as follows:

(*a*) A magnetic system situated below the earth's surface whose axis is directed about opposite to that of the primary internal field and is displaced in longitude at present about 68° to the west. Chiefly as the result of this demagnetizing system, the earth's magnetic moment is apparently at present being diminished by about $\frac{1}{2400}$ part annually.

(*b*) A magnetic system situated above the earth's surface, whose axis is directed almost transverse to the axis of rotation and is displaced in longitude at present about 151° to the west of that of the primary internal field and about 83° to the west of that of the inter-

nal secular variation system. This system plays an important part in the secular variation of the magnetic declination.

(2) The secular variation of the earth's magnetism is caused not only by a change in the direction of the magnetization, but likewise by a change in the intensity of magnetization.

These results, if true, are of such importance that it is essential they be tested at the earliest possible moment with the aid of new and more comprehensively distributed data. Accordingly the selection and establishment of a series of secular-variation stations over the globe, at which observations shall be made at regular intervals of about five years, has been undertaken and observations have been begun as related under "Field work."

INVESTIGATION II.—*Discussion and publication of the data on the magnetic perturbations observed during the eruption of Mont Pelé, Martinique, 1902.*—Good progress has been made with this investigation under the direction of Mr. J. A. Fleming, magnetician in charge. It is hoped that the completed manuscript can be submitted for publication before very long. Principal assistance was rendered in this work by Dr. S. Tetsu Tamura and Mr. A. H. Homrighaus.

INVESTIGATION III.—*A general study of the laws of the diurnal variation to serve as the basis for determining corrections and their reliability for the reduction of field observations.*—A paper under this head on the "Diurnal motion of a free magnetic needle" will soon be ready for publication. It will contain results helping to elucidate the dependence of the diurnal variation at a given station upon latitude and longitude.

INVESTIGATION IV.—*Special investigation of magnetic storms with the view of determining a working method for the discussion and analysis of such fluctuations.*—These studies are being conducted, since January, under the direction of Prof. Adolf Schmidt, in charge of the Potsdam Magnetic Observatory, with the aid of funds to the amount of $750 supplied, with the approval of the Executive Committee, by the department. Professor Schmidt has access, for this purpose, to copies of notable magnetic storms, received from coöperating magnetic observatories over the entire globe. He has made a preliminary report covering the work up to the end of August, from which it is evident that excellent progress has been made. A "first communication" will doubtless be ready for publication by the end of the year and will contain the analysis of the fluctuations occurring on two "term" days of the international "polar" year, viz, March 15

and July 1, 1883. Professor Schmidt has been assisted principally by Drs. Nippoldt and Brückmann, both of the Potsdam Observatory staff, who have taken charge for him of the work of the computers especially employed for this investigation.

V. *Miscellaneous.*—The preparation of a card catalogue of publications and investigations in terrestrial magnetism and terrestrial electricity and allied subjects has been continued, as also the collecting of information of work done and being done, so as to avoid as far as possible needless duplication. A summary of papers on "Earth currents" has been published in the March, 1905, issue of the journal "Terrestrial Magnetism and Atmospheric Electricity," by Mr. J. E. Burbank, magnetician, under the title "Earth currents and a proposed method for their investigation." He also completed for the department a first compilation of the "Earthquake disturbances recorded on the magnetographs of the United States Coast and Geodetic Survey," the records having been kindly put at his disposal for this purpose by Mr. O. H. Tittmann, Superintendent of the Coast and Geodetic Survey. This has been published in the September issue of the said journal. A second compilation is in preparation.

FIELD WORK PERFORMED.

In pursuance of the plan for the completion of a general magnetic survey of the accessible regions of the globe within a period of 15 to 20 years and of the general investigation of the secular variation, the following observational work is now in actual progress:

A. Magnetic Survey of the North Pacific Ocean.

A wooden sailing-vessel, the brig *Galilee*, of San Francisco, built in 1891· length, 132.5 feet; breadth, 33.5 feet; depth, 12.7 feet; displacement, about 600 tons, carrying a crew of ten men and sailing master—was chartered of Matthew Turner, of San Francisco, and was fully adapted for the purposes of the expedition.

After the various necessary alterations were made, *e. g.*, substitution of the steel rigging by hemp rigging, etc., the vessel, after having been inspected by the President of the Institution, entered upon her duties early in August. Magnetic observations were made at various places on the shores around San Francisco Bay, and the most suitable place for swinging ship by their aid was determined. The ship was swung with the aid of a tug on August 2, 3, and 4, in San Francisco Bay, between Goat Island and Berkeley, California, and the various deviation coefficients were determined.

On August 5 the *Galilee* sailed from San Francisco, secured magnetic observations daily to a greater or less extent, according to conditions of the weather and sea, swung twice under sail, and arrived at San Diego August 12. This first short cruise was an experimental one, various instruments and methods having been subjected to trials under the direction of the director, who accompanied the expedition as far as San Diego. The deflection apparatus devised by him for determining horizontal intensity has proven successful. In a separate communication the methods, instruments, and results will be more fully described.

After some further alterations had been made at San Diego and the deviation coefficients had been redetermined, the *Galilee* again set sail on September 1, this time for the Hawaiian and Midway Islands, and is expected to return to San Francisco about December 1. After these two experimental voyages, she is to sail from San Francisco early in 1906 on a more lengthy cruise—one embracing the entire circuit of the North Pacific Ocean—if the necessary funds have been provided.

The present scientific leader and commander of the vessel, Mr. J. F. Pratt, of the United States Coast and Geodetic Survey, has had thirty years' experience in astronomical, geodetic, hydrographic, and magnetic work, and has had command of both sailing-vessels and steamers engaged in coast survey work. By the courtesy of the Secretary of Commerce and Labor and the Superintendent of the Coast and Geodetic Survey, he was granted the necessary furlough, and entered the temporary employ of the Institution for the purpose of assisting in the inauguration of the magnetic survey of oceanic areas. The vessel was prepared for the purposes of the expedition under his superintendence. The other members of the scientific corps are Dr. J. Hobart Egbert, magnetic observer, surgeon, and naturalist; Mr. J. P. Ault, magnetic observer, and Mr. P. C. Whitney, magnetic observer and watch officer. The sailing master is Capt. J. T. Hayes, who has made some record sailing trips in the *Galilee*—one voyage of 3,000 miles from the South Pacific islands to San Francisco in fifteen days, and having made as much as 308 miles in one day.

The successful and expeditious inauguration of this promising work is due in no small degree to the active and hearty coöperation extended on all sides. Especial acknowledgments of valuable advice given and assistance rendered are due Capt. E. W. Creak, formerly superintendent of the compass department of the British Admiralty, now retired; Mr. O. H. Tittmann, Superintendent of the United States Coast and Geodetic Survey, and to the officers of his staff, notably

Mr. F. W. Perkins, the assistant superintendent, and Mr. H. O. Ogden, inspector of hydrography.

To Mr. G. W. Littlehales, the consulting hydrographer of the department, belongs the credit of the selection of a vessel from which apparently results of high order of accuracy are being obtained. The physical conditions controlling the proposed circumnavigation of the North Pacific Ocean were investigated by him and submitted in the form of a digest for the guidance of the commander. He has likewise collected and compiled the existing magnetic observations at shore stations in the North Pacific Ocean and in other regions of the globe where work was being arranged for by the department.

The important initial work connected with the testing of the instruments at Washington devolved principally upon my chief assistant, Mr. J. A. Fleming, and upon Dr. Egbert.

It is gratifying to report that the German government, in response to a request from the President of the Institution, has given the desired assurance that its Samoan magnetic observatory will be maintained until 1909 to assist in the magnetic survey of the Pacific Ocean. Furthermore, during the director's visit to European institutions, in the early part of the year, assurance was everywhere received of hearty coöperation and substantial assistance rendered.

Special mention should likewise be made of the fact that the United States Government, through its Department of Commerce and Labor, at the request of the President of the Institution, has extended to the *Galilee* special privileges and has classified her as a yacht in order to enable her to pass from port to port without the usual custom-house formalities, thus greatly facilitating the operations of the vessel.

B. Land Work.

Mr. J. P. Ault, magnetic observer, preliminary to his assignment to the ocean work, was temporarily attached to the Coast Survey steamer *Bache* for securing the necessary training in magnetic work on a cruise from Baltimore to Panama. Besides taking part in the sea work, he determined the three magnetic elements at the following stations: Norfolk (Virginia), Key West and Miami (Florida), Kingston (Jamaica), Colon (Panama), Havana, Matanzas, Batabano, and Pinar del Rio (all in Cuba), and Waycross (Georgia). At Havana comparisons were also made with the instruments of the Colegio de Belen. His work in Cuba was done in coöperation with the Havana Magnetic Observatory, whose director, Father Gangoiti, extended to Mr. Ault every courtesy possible.

Mr. D. C. Sowers, magnetic observer, accompanied the new Coast Survey steamer *Explorer* from Baltimore to Porto Rico, determined

the magnetic elements on land at Norfolk (Virginia), San Juan and Vieques (Porto Rico), and took part in the sea work. Toward the end of May he entered upon a trip through the Windward and Leeward islands and determined the magnetic elements at the following stations, at many of which observations had previously been made: Charlotte Amelia (St. Thomas), Phillipsburg (St. Martin), Crocus Bay (Anguilla), Christiansted (St. Croix), Basse Terre (St. Christopher), Charlestown (Nevis), St. Johns (Antigua), Codrington (Barbuda), Plymouth (Montserrat), Basse Terre, Point à Pitre, and Le Moule (Guadeloupe), Grand Bourg (Marie Gallante), Roseau (Dominica), Fort de France (Martinique), Port Castries (St. Lucia), Bridgetown (Barbados), Kingstown (St. Vincent), St. George (Grenada), Port of Spain, San Fernando, and Sangre Grande (Trinidad), Scarboro (Tobago), and Caracas (Venezuela). At San Fernando (Trinidad) he carried out extensive observations of dip in different azimuths for the purpose of discussing inequalities of pivots of needles.

He has thus satisfactorily completed, without mishap or delay, a piece of work requiring special care, good judgment, and skill. All of these stations have been permanently marked to serve for future use by the department, as well as by others.

Mr. G. Heimbrod, formerly surveyor of Suva, Fiji Islands, entered the employ of the department in September. After assisting Dr. Franz Linke, in charge of the German magnetic observatory at Apia, Samoa, and securing the necessary experience in magnetic and electrical work, he will be engaged in determining the magnetic elements on various islands in the South Pacific.

Definite arrangements are furthermore being perfected for securing in the near future observations along the coasts in Canada, Mexico, Central American countries, South America, and China while the oceanic survey is progressing.

The work in China will be conducted by Prof. Charles K. Edmunds, Ph. D. (Johns Hopkins University), who at present is professor of physics and of electrical engineering in the Christian College at Macao, China. He has already secured the necessary experience in magnetic work, as he was previously in the service of the Coast and Geodetic Survey as a magnetic observer. He is now engaged in the formulation of the plans in coöperation with Father J. de Moidrey, director of the Zi-ka-wei Observatory.

In connection with the eclipse work, elsewhere related, important secular variation and distribution data have also been secured in Canada, Newfoundland, and Labrador.

The work under this head has been greatly facilitated by the special arrangements made at the instance of the late Secretary of State, Mr. John Hay, respecting free entry of the magnetic instruments in foreign ports and the soliciting of the special coöperation of consular and diplomatic officers.

In connection with the land and sea work it has become essential to make some experimental investigations at Washington with the special view of ascertaining the cause of outstanding instrumental differences, the reliability in the application of corrections derived by comparison, and the changes in the corrections for any particular set of instruments when used in various magnetic latitudes. These studies have an important bearing upon the inter-comparison and reduction of observatory standards, as well as the standardization and testing of instruments designed for field use.

C. Eclipse Work.

In response to the appeal of the department and in accordance with the program of proposed work published in various journals for simultaneous magnetic and allied observations during the total solar eclipse of August 30 last, coöperative work was conducted at stations distributed over the entire belt of totality, every civilized nation participating.

The supplementary stations finally decided upon by the department in order to still further provide for the proper distribution and successful study of the subject under investigation were as follows:

Labrador: Battle Harbor (magnetograph, atmospheric electricity observations, and declination eye-readings, the whole under the direction of Mr. J. E. Burbank, assisted by Messrs. Bowen and Homrighaus) and Turnavik (magnetic declination eye-readings by Mr. G. L. Hosmer, of the Massachusetts Institute of Technology). Both parties were supplied with full sets of absolute instruments, with which important magnetic secular variation and magnetic distribution data were obtained en route and returning. As the Canadian magnetic expedition, under the direction of Professor Stupart, located its station in Labrador within the belt of totality, the above stations were selected so as to have one immediately south of the belt and the other about the same distance north. Dr. W. G. Cady, of the Wesleyan University, also made magnetic observations at Black Point, Nova Scotia, and Dr. L. A. Bauer, assisted by Prof. W. C. Bauer, of Baker University, observed at Missinaibi, Ontario, Canada.

In addition, Professors Elster, Geitel, and Dr. Harms successfully made special atmospheric electricity observations at Palma, Majorca.

The department also availed itself of the skill and experience of Professor Palazzo, director of the meteorological and magnetic service of Italy, and arranged for magnetic, electric, and meteorological observations under his direction at Tripoli, all of which work, according to information received from him, was successfully carried out.

Coöperative observations were made under the auspices of the United States Coast and Geodetic Survey at Pembina, North Dakota, by Prof. H. W. Fisk, of Fargo College; at Wausau, Wisconsin, by Mr. C. C. Craft; at Colebrook, New Hampshire, by Dr. G. B. Pegram, of Columbia University, and at the various magnetic observatories. At the Cheltenham Magnetic Observatory both special magnetic and electric observations were made under the direction of the observer in charge, Mr. W. F. Wallis.

At all of these places the program of work prescribed by the department was successfully executed.

These stations, in addition to those occupied by other countries, will afford a unique and most valuable collection of data covering the entire belt of totality.

The hearty coöperation of foreign countries has been very gratifying. Russia, to complete the distribution of stations along the belt of totality, sent, under the auspices of the St. Petersburg Academy of Sciences, an expedition specially equipped for magnetic work and placed it under the direction of one of its most experienced magneticians, Mr. W. Dubinsky, in charge of the Pawlovsk magnetic observatory. Other European countries were no less zealous, and likewise either sent special expeditions equipped for magnetic and electric work under the direction of able and experienced observers or made special arrangements for careful and comprehensive observations at their home stations.

According to the reports already received from observers in the United States and Canada, the eclipse interval was a rather disturbed one, due to a cosmic magnetic storm, the magnetic disturbances having in fact begun several days before the day of the eclipse. During the night of August 29 and 30 brilliant polar lights were visible at the northern stations.

At the director's station (Missinaibi, Canada, 48° 28′.6 N. and 5h. 33.9m. west of Greenwich), in addition to the disturbances already referred to, there was a smaller fluctuation about the time of maximum obscuration of the sun of the character and amount to be expected as the eclipse effect, as judged by previous eclipses. However, whether this particular fluctuation is really to be referred to the eclipse can not be stated definitely until the records have come

in from other stations. If it is found that the characteristic features of this fluctuation did not take place simultaneously at widely distant stations, but progressed in accordance with the passage of the shadow cone, the presumption will be strong that an eclipse effect has again been detected. A fuller report must be reserved for a future occasion.

D. Magnetic Disturbances

For studying the correlation between solar phenomena and magnetic disturbances, coöperative work has been entered into between the Solar Observatory and the Department of Terrestrial Magnetism. Two direct recording variometers, giving a continuous visual record of the magnetic fluctuations and ringing an electric alarm for disturbances of a certain magnitude, have been constructed under the direction of Dr. W. G. Cady, research magnetician, in accordance with his design. One of these instruments has been supplied to the Solar Observatory and the other was used by Dr. Cady at Black Point, Nova Scotia, in connection with the eclipse observations.

This may be a promising step toward working out a general plan for enlisting in magnetic work the coöperation of certain favorably situated and well-established institutions, such as astronomical observatories, in order to assist in bringing about a more uniform distribution of stations contributing magnetic data.

E. Atmospheric Electricity Work.

To enable the department to keep in touch with the latest developments in this work, Mr. J. E. Burbank, magnetician, spent three months last spring in Germany in order to secure the necessary training under the guidance of Professors Elster and Geitel, of Wolfenbüttel, and Professor Wiechert and Dr. Gerdien, of the University of Göttingen. Every facility and courtesy were extended by these gentlemen to Mr. Burbank, on account of which and for other aid rendered the department is under grateful obligation. A proposal having the indorsement of these eminent investigators regarding the work in atmospheric electricity which the Institution may find it beneficial to encourage will be submitted at a later occasion.

Mr. Burbank, while abroad, likewise attended to the purchasing and testing of magnetic and electric instruments for the department, and also familiarized himself with the highly interesting work in seismology conducted under the direction of Professor Wiechert at the Geophysical Institute, which occupies such an enviable position in geophysical research. On his return he made a successful and important series of atmospheric electricity observations at sea, an

account of which will be found in the journal Terrestrial Magnetism and Atmospheric Electricity for September.

CONCLUDING REMARKS.

In September, at Innsbruck, Austria, occurred a meeting of the International Committee on Terrestrial Magnetism and Atmospheric Electricity, of which the director is a member. He was prevented from attending it because of the duties devolving upon him in connection with the magnetic survey of the North Pacific Ocean and the international magnetic observations during the total solar eclipse of August 30. In conformity with the views of the President of the Institution, the director, however, submitted to the committee in the form of a letter a statement of the attitude of the department regarding certain propositions. The general policy of the department, furthermore, was made clear, viz, not to supplant any existing organization in the work already undertaken, but rather to supplement and to coöperate in the most effective manner.

The committee was also informed of the initial steps already taken by the Institution to secure within a reasonable period a complete magnetic survey of the globe, and to obtain the data required for a successful study of the secular variation. With this end in view, it was stated that the Institution would confine its work almost entirely to unexplored areas and to the oceanic areas, and that it remained, however, for the members of the committee to see to it that magnetic surveys were energetically prosecuted in the countries and colonies which they represented.

The committee, in view of these statements, has unanimously expressed its opinion as to the desirability of an effective coöperation between the various governmental institutions engaged in magnetic and electric researches with this department. In order to come to an agreement as to how this can best be done, they appointed a subcommittee, consisting of eminent and influential investigators, to arrange with the department as to the necessary details. It is thus evident that the confidence, good will, and united support of magneticians and organizations the world over have been secured.

ZOÖLOGY.

Blakeslee, Alfred F., Botanisches Institut, Halle, Germany. Grant No. 160. *Investigation of sexuality in lower fungi.* $1,000.

Abstract of Report.—The grant was made for investigation at German universities, and Dr. Blakeslee reports from Germany that it seems desirable to continue the work on the sexuality of black molds (Mucors). It is found that the two sexes separate in distinct races, and are apparently capable of keeping their sexual character to an indefinite number of generations by non-sexual reproduction.

The preliminary summary of the previous work has been published in Science, n. s., vol. 19, p. 864. The importance of the subject to botanical physiology may be inferred by reference to Professor Duggar's address before the International Science Congress in St. Louis (see 23d issue of Science, 1905, p. 951). The sexual spores are very capricious and difficult to germinate, requiring, when they germinate at all, a wait of upward of five months after being sown. Only in the case of two species, from a large number attempted, have germinations been obtained. In one of these the non-sexual spores resulting from the germination are male, female, and hermaphroditic. The non-sexual spores from the hermaphroditic plants in turn produce male, female, and hermaphroditic spores. The hermaphroditic condition not being transmitted to all the non-sexual offspring, it is necessary to carry on the hermaphroditic plants in a poor condition to make the transfers of the vegetative growth every other day. Many interesting problems with this hermaphroditic race present themselves. The influence of external conditions upon the determination of the sex ought to be tested, since the race is apparently in a labile condition.

During the present year Dr. Blakeslee has discovered the sexual spores and determined the sexual conditions in the following forms: *Circinella*, *Absidia repens*, *Absidia* sp. (?), *Helicostylum*, *Syncephalestrum*, *Cunninghamella*, and several of the genus *Mucor*. In these forms, with the possible exception of *Circinella*, the sexual spores had never been known. By finding the sexual spores of *Cunninghamella*, the position of this species among the Mucors is established, whereas it had formerly been classed as one of the Fungi Imperfecti in the genus *Oedocephalum*. Dr. Blakeslee has in process of publication in the Botanical Gazette an article on this species and on a unique new genus which shows relationships with the Mucors. Finally, by germination of the zygospores, he has obtained in one species an hermaphroditic race in addition to the male and female races which are characteristics of the species.

Castle, W. E., and **Mark, E. L.,** Harvard University, Cambridge, Massachusetts. Grant No. 249. *Experimental studies in heredity.* (For first report see Year Book No. 3, p. 136.) $600.*

Drs. Castle and Mark are associates of the Station for Experimental Evolution at Cold Spring Harbor, and their work has been done in coöperation with that of the station.

Abstracts of Reports.—Dr. Castle reports that most of the experiments in progress a year ago have been continued up to the present time. A large amount of valuable material has been accumulated and in part studied. About 2,400 guinea-pigs and 450 rabbits have been reared from pedigreed stock. Experience acquired in previous years has enabled the investigators to avoid certain difficulties in winter breeding, so that the animals have been kept quite free from disease and have bred throughout the year without interruption.

The experiments and observations relate chiefly to inheritance of coat and skin pigments, hair length, hair arrangement, polydactylism, mammæ, individual size, and sex. Some selection experiments for the fixation of particular color patterns have yielded interesting results and promise much for the future. Some light has been thrown upon the phenomena of latent inheritance and reversion. A fine example of blending inheritance has been found in the heredity of ear-character in rabbits.

Two brief papers and one of a more extended nature have been published during the year, based upon the results obtained from these experiments. Another detailed paper is in preparation.

Dr. Mark reports that through the generous coöperation of Dr. Davenport the material necessary for the studies has been bred and will soon be ready for histological study. The grant was to pay for the cost of making the necessary histological preparation.

Crampton, Henry E., Columbia University, New York, N.Y. Grant No. 137. *Determination of the laws of variation and inheritance of certain Lepidoptera.* (For previous reports see Year Book No. 2, p. xli, and Year Book No. 3, p. 136.) $500.

Report.—During the past year efforts have been directed toward the acquisition of an abundance of pedigreed material of the saturnid moth *Philosamia cynthia.* More than 800 members of the first and second pedigreed generations obtained in 1904 emerged during May and June, 1905. These were mated when possible, and statistics relating to more than 300 families were obtained. As upward of 31,000 eggs were deposited by the female moths, it was manifestly

* Of this amount $500 was allotted to Dr. Castle and $100 to Dr. Mark.

impossible to rear all of the progeny. Fifty-seven families of one series, whose parents were perfect in every way, were selected for further rearing and gave over 2,900 pupæ in July, 1905. From the members of the second series of 1904, 80 matings were made, giving 7,000 eggs, and from 28 families of this group about 1,100 living pupæ were obtained.

Although it was expected that the second series would be double-brooded throughout, this was not the case. Specifically, 105 emerged, while more than 500 of the first series emerged in August, 1905. The moths that emerged were mated in 190 instances, and furnished about 27,000 eggs, and from 39 families of these were reared about 1,000 pupæ of the third and fourth pedigreed generations.

Statistics relating to the characters of both larvæ and pupæ have been determined in all cases, while the adults that have emerged are available for further determinations. This material, together with that of the preceding year, gives statistics of more than 700 matings in this species alone, while the members of over 150 families have been reared. Having, then, the characters of 6,000 pedigreed individuals, it will be possible to prosecute an extensive study of many problems, such as the variation of morphological and physiological characters of the several stages; the phenomena of selection; the strength of correlation between and among the several characters of larvæ, pupæ, and moths; the correlation of fertility with these characters; the inheritance of sex, and the strength of inheritance of characters other than sex.

Duerden, James E., Rhodes University College, Cape Colony. Grant No. 288. *Continuation of investigations on the morphology and development of recent and fossil corals and physiology of the Zoantharia.* (For previous reports see Year Book No. 2, p. xli, and Year Book No. 3, p. 137.) $750.

Abstract of Report—(a) Morphology and Development of Recent Corals.—During the past academic year investigations were continued, with the help of an assistant, upon the Pacific corals collected by Dr. Duerden last year in the Hawaiian Islands. Certain morphological details not occurring in West Indian corals have been disclosed, though on the whole the researches but serve to demonstrate the uniformity of structural plan of the Madreporaria as a whole. Among the new morphological features are (1) the presence of a well-defined, diffuse nervous system in the coral *Cœnopsammia*, and (2) the occurrence of much modified permanently invaginated

tentacles in *Pocillopora*. A paper on the first subject has been submitted for publication, and one on the second is nearly completed.

Among the large number of dried coral collected are certain forms very suitable for a study of variation by biometrical methods. Work has already been begun upon two species and promises results of some interest as regards the possible variations within a species.

(*b*) *Fossil Corals*.—A contribution, "The Morphology of the Madreporaria; VI, The Fossula in Rugose Corals," has already been published. The paper is a study of the rugose corals along developmental lines, with the object of arriving at the nature of the fossula. It is therein shown that the two lateral fossulæ correspond with development stages in the growth of the septa, while the cardinal fossula is in addition probably to be associated with the presence in the polyp of a siphonoglyph. From this support is gained for the author's previous contention that the Rugosa are closely related to the modern Zoanthid actinians.

(*c*) *Physiology of the Zoantharia*.—While in the Hawaiian Islands experiments and observations were made upon the living activities of coral polyps, and the preparation for publication of the results has been continued. A paper, "The Rôle of Mucus in Corals," is now completed. The paper discusses the conditions under which mucus is exuded and its importance as a protection to the polypal surface, and also in the entanglement and ingestion of food substances.

A second contribution, "The Habits and Reactions of Crabs Bearing Actinians in their Claws," is almost completed for publication. The paper is a result of observations and experiments conducted upon the crab *Melia tessellata*, and discusses the mutual relationships of the crab and its commensal actinians, the reactions of one toward the other, the manner in which the combination is brought, and the peculiarities which each exhibits in correlation with the commensal habit.

Eigenmann, C. H., Indiana University, Bloomington, Indiana. Grant No. 68. *Investigation on the blind fishes in the caves of Cuba*. (For previous reports see Year Book No. 2, p. xlii, and Year Book No. 3, p. 138.) $1,000.

Abstract of Report.—During the past year nearly all the necessary sections for the anatomy of the eye of *Stygicola* were cut and correspondence was carried on concerning the rearing of the blind fishes at the Tortugas Station. During June and July Mr. John Hoseman, accompanied by Mr. McIndoo as volunteer assistant, was collecting in the caves of Cuba to secure embryos. It is expected that the final report of the work will be presented shortly.

Griffin, Lawrence E., Missouri Valley College, Marshall, Missouri. Grant No. 81. *Expenses of a trip to the Philippine Islands in order to secure material for a study of the embryology, histology, and physiology of the Nautilus.* $1,000.

Abstract of Report.—Professor Griffin went first to the locality where Mr. Dean C. Worcester secured his Nautili in 1891, the town of Manjuyod, on the eastern coast of the southern part of Negros. After the traps were put out a large cage was built of bamboo, in which Nautili could be kept at a depth of 15 or 20 fathoms. The inside of the cage was hung with sacking, in the hope that the Nautili would attach their eggs to the folds. Under many adverse conditions, as stated in the full report, several lots of Nautili were placed in the cage, but all died without depositing eggs. Prof. Griffin considers it doubtful if any of them revived from the half-dead condition they were in after being hauled up from the great depths in which they live and the long journey to shore. While the cage experiments were in progress he was preserving specimens which were too far gone to revive in the water, as well as the extra males for histological and anatomical study.

As far as securing the embryology of *Nautilus* is concerned, the expedition failed; but material was secured for the further study of the anatomy of *Nautilus* and for a complete study of the histology of this unique form. Work on them will commence soon.

Howard, L. O., Department of Agriculture, Washington, District of Columbia. Grant No. 250. *Preparation of an elaborate monograph on American mosquitoes.* (For previous reports see Year Book No. 2, p. xlii, and Year Book No. 3, p. 138.) $3,000.

Abstract of Report.—Considering that the mosquito fauna of the main inhabited regions of the United States has been rather fully worked up by the investigations of the last two years, an especial effort has been made during the season of 1905 to secure material representing the mosquito fauna of south Mexico, Central America, West Indies, and Alaska.

A trained observer, Mr. Frederick Knab, was sent to south Mexico, and reports considerable success. One important result of his work has been to show that the yellow-fever mosquito (*Stegomyia fasciata*) occurs on every point on the Pacific coast where he has stopped, from Salina Cruz southward. While it was quite to be supposed that this would be the case, there has up to this time been no authentic record of the fact. This observer proceeded southward to Salvador and

Costa Rica, and made large collections, including two new to the collection, both of which are new to science.

Mr. A Busck spent the summer in the West India Islands and brought together a large collection, many of which he succeeded in rearing from the larvæ. From his results and those of voluntary observers during the summer, 20 species new to the collection were brought together, of which 6 are new to science, 2 belonging to genera not yet characterized. No less than 33 species were reared from the larvæ.

The voluntary observer in Alaska has accomplished no results.

In all there have been obtained in the course of the investigation 128 species of mosquitoes from North and Middle America (Central America and the West Indies); but 8 of these belong to the short-billed mosquitoes of the family Corethrinæ, now placed in the Dixidæ.

Much work has been done during the year in regard to illustration and there are now finished drawings as follows: Drawings of adults from North America, 68 species; drawings of eggs, 31 species; drawings of pupæ, 14 species; complete drawings of larvæ, 28, representing 27 species; drawings of details of larval structure, 367, representing 56 species. The drawings of the adults are in pen and ink; those of the larvæ and pupæ are in wash ink, while the eggs and details of the larvæ are in charcoal. This enumeration of drawings does not include field sketches.

The important bearing of the work has already been shown in a striking way by the fact that the Public Health and Marine Hospital Service, during the yellow-fever epidemic of the past summer, has based its quarantine regulations entirely on the results of the studies of the geographic distribution of *Stegomyia fasciata* made during the summer of 1904 and referred to in the report of last year.

Lillie, Ralph S., University of Nebraska, Lincoln, Nebraska. Grant No. 166. *Study of the relation of ions to the various forms of protoplasmic movement.* $1,000.

Abstract of Report.—Dr. Lillie continued the investigation of the subject and reports on the following subdivisions:

I. Physiology of Cell-division.

The conditions determining the disposition of the chromatic filaments and chromosomes in mitosis.—The attempt was made to simulate the arrangements exhibited by chromatic filaments and chromosomes at the different stages of cell-division by the use of mutually repellent models composed of groups of floating, similarly oriented, mag-

netized needles. Groups of these when brought close together by the action of a centrally attracting magnetic force are found to exhibit arrangements closely similar to those shown by chromatic filaments and chromosomes in the dividing cell. In this manner different types of spireme formations, equatorial plates (both those with chromosomes arranged in a ring and those with chromosomes uniformly distributed over the area of the plate) can be imitated. The aggregation of the chromosomes in a single plane midway between the two polar areas can be simulated by the combination of a central attractive and two polar repellent magnetic poles. The inference is that the chromosomes exert electrostatic repulsions on one other (due to their being colloid aggregates of like sign) and that this mutual repulsion is the chief factor in determining their disposition; also that the astral centers in mitosis *repel* the chromosomes. Since the chromosomes carry negative charges, the astral centers must represent electrically negative areas. There is therefore an electrical field within the cell to which the disposition of the astral rays, etc., is regarded as due.

II. Action of Salt Solutions on Ciliated Epithelium.

The gill filaments of *Mytilus edulis* were used in this investigation. The chief general results are as follows:

(1) Of alkali salts in pure solutions of single salts (*e. g.*, chlorides) the order of destructiveness is as follows: Li, Na, NH_4, K. In solutions of K salts activity may last several hours. Cs and Rb resemble K in action.

(2) Na salts are peculiar in that their destructive action is readily counteracted to a greater or less degree by the addition of various salts with bi-, tri-, and tetra-valent cations. Anions are inactive.

(3) Trivalent and tetravalent salts exercise this antitoxic action in much lower dilution than bivalent, and tetravalent in somewhat lower dilution than trivalent.

(4) In the case of salts with bivalent cations a relation apparently exists between the decomposition voltage of the cation and its poisonous or antitoxic action. The valence of the cation seems to be a factor of equal if not of greater importance in this action.

(5) The toxicity of Na salts with different anions is not antagonized with equal readiness in all cases. In general those salts whose anions have high decomposition-voltages are least toxic in pure solutions, and their toxicity is antagonized most readily. The possession of a low decomposition-voltage confers a corresponding toxicity on the anion and the salt can not be so readily antagonized.

(6) Salts of certain bivalent metals have a destructive action which is antagonized by the addition of other salts with powerfully acting

anions, e. g., the toxicity of $SrCl_2$—which is quickly destructive in pure solutions—is greatly diminished by the addition of small quantities of Na salts with the anions OH, AsO_3, CN, BrO_3. The action of the cation preponderates in the salt, and hence addition of anions has an antitoxic action.

(7) The action of the cations is, in general, to cause coagulation of the protoplasm of the ciliated cell, while the anions cause absorption of water, indicating the reverse effect. The effect is, in general, more marked, the lower the decomposition-voltage and the greater the valence of the anion. Ionic velocity also appears to play a part in this action.

III. CONTRACTILITY OF SWIMMING PLATE OF CTENOPHORE.

The research was conducted at the Zoölogical Station, Naples. The swimming plate of *Eucharis lobata* was chiefly used.

(1) An extensive study of the action of salts was made. In general the results of this correspond to those summarized above for the ciliated cell of *Mytilus*, with various typical differences to be described in the full report.

(2) A connection between a coagulation of the colloids of the swimming plate and the contractility of the plate was found to exist. Contractility apparently depends on a change in the aggregation-state of the colloids similar to that which occurs in coagulation, *i. e.*, a coalescence of adjacent colloid particles. In the living and active plate the change is apparently reversible in its nature.

(3) In the propagation of the contraction-impulse from one plate to the next, continuity of the ciliated cells is not necessary. Apparently the impulse can be transmitted across the general surface of the jelly composing the body of the animal.

McClung, C. E., Kansas University, Lawrence, Kansas. Grant No. 16. *Comparative study of the spermatogenesis of insects.* (For previous reports see Year Book No. 2, p. xliii, and Year Book No. 3, p. 139.) $500.

Abstract of Report.—The investigations have been continued with the purpose of discovering whether there is any constancy in the chromosome complex of the germ cells and, if there is, whether there is any discoverable connection between particular chromosomes and definite groups of body characters. By the study of a considerable number of species belonging to the family Acridiidæ it has been found that there is a constant number of chromosomes for the family, and that different genera have characteristic sizes and group-

ings of the chromosomes. The species in the genera are distinguishable by variations in size of the chromosomes and other cell parts. Corroborative evidence is afforded by other families of the Orthoptera. The results so far would indicate that the chromosomes are highly organized, self-perpetuating elements of constant sizes and relationships in the different species. Sufficient data have not been accumulated to establish any relationship between a particular chromosome and a group of somatic characters. The hypothesis that the accessory chromosome governs the development of the male germ cells seems more probable as the work progresses, and forms a possible exception to the preceding statement.

Morse, Albert P., Wellesley, Massachusetts. Grant No. 284. *Research on North American Acridiidæ, with especial reference to biology, distribution, and variation.* (Continuation of Grant No. 84.) $1,000.

Abstract of Report.—The work consists thus far of a field-work trip of ten weeks' duration, July 5 to September 13. At the beginning of the year it was planned to make a general reconnoissance of the next group of States to the west of the area studied in 1903, viz, Tennessee, Mississippi, Alabama, Arkansas, and Louisiana. After two weeks in the field it became necessary, owing to the interruption to travel caused by the outbreak of yellow fever, to postpone examination of this region until a more favorable time. The remainder of the reason was spent in western Arkansas, Indian Territory, Oklahoma, and northern Texas. The material collected, comprising several thousand specimens, is being prepared for study, and a full report will be submitted when it has been examined.

Patten, William, Dartmouth College, Hanover, New Hampshire. Grant No. 157. *Investigations relating to the origin of vertebrates.* (For first report see Year Book No. 3, p. 140.) $500.

A report of the field work accomplished in New Brunswick during the summer of 1904 has been submitted. All the large slabs and nodules containing those specimens of *Bothriolepis*, the finding of which was the special object of the expedition, are now uncovered or completely removed from the matrix. This material is more abundant and in a more perfect condition of preservation than any of a similar nature that has ever been obtained before. It enables us for the first time not only to reproduce the external shape and structure of the body of these remarkable animals down to the minutest details, but to learn also something of their internal anatomy. It also gives us a most vivid picture of the daily life of these animals

at that remote period, such as the nature of their food, their mode of swimming freely in shallow waters, or of crawling about in great schools on the sandy bottom; the relation of their migrations to tidal currents, as indicated by the constant correspondence between their positions and the axes of the ripple-marks and the position of the stems of accompanying plants.

The structural features discovered that are new to science and are of special importance or of general interest are as follows:

(1) The jaws, heretofore supposed to be absent, consist of four separate plates, of peculiar shape, held in place by membranes only, and in life, as their structure clearly shows, acting against each other laterally like the jaws of an arthropod, not forward and backward in the typical vertebrate fashion.

(2) The location of the olfactory pits on the dorsal side, within the large openings containing the eyes.

(3) The presence of three pineal (or ocellar) eye-pits.

(4) The shape and arrangement of the plates and membranes covering the stalked lateral eyes, and the method of raising and lowering the eyes during life.

(5) The presence of broad, membranous folds, of unknown function, around the posterior end of the cephalic buckler.

(6) The presence of a very slender, naked trunk and tail, with two dorsal fins, lateral folds, and a terminal fin, all of an unusual structure.

(7) The structure and relations of some of the internal organs it is now certain can be determined with some degree of accuracy, such as (*a*) the shape and location of the mouth; (*b*) the shape of the brain chamber; (*c*) the presence of a relatively small body suspended by tough connective tissue from the median dorsal wall of the buckler and hanging freely into (*d*) a large peri-branchial chamber; (*f*) the presence of seven pairs of broad lamellæ, representing, in whole or in part, the gills; (*g*) the exact location of the rectum, anus, and abdominal pores, with accompanying plate-like scales.

Preliminary papers describing some of the above facts were read before the American Society of Paleontologists and the American Society of Morphologists, at Philadelphia, in December, 1904, and some of the specimens were exhibited there at that time. These papers were based partly on specimens obtained in an earlier exploration and in part on those obtained by the grant from the Carnegie Institution of Washington.

The work now in progress consists of the preparation of photographs, drawings, models of the external form, and the preparation of thin, polished, serial sections of the whole animal to display the structure of the internal organs.

Pearl, Raymond, University of Michigan, Ann Arbor, Michigan. Grant No. 266. *Investigation by statistical methods of correlation in variation.* (For first report see Year Book No 3, p. 140.) $1,250.

Abstract of Report.—During the year the work has been carried forward mainly on the following lines:

(*a*) Variation and correlation in *Ceratophyllum*. An extensive series of material on this form, affording data on the problems (1) variation within the individual organism, and (2 geographical variation, has been collected and almost completely reduced. The laws of growth of the plant have been especially studied and the facts regarding the relation of the variation to these laws worked out.

(*b*) Correlation in the crayfish, with special reference to morphological factors. The reduction of the material on the crayfish has been completed and a preliminary paper is now in press.

(*c*) The effect of environmental changes of known quality and intensity on variation and correlation in the Protozoa. Measurements of over 6,000 individual Paramecia, reared under controlled conditions and in pure strains, have now been collected and partially reduced. For purposes of comparison data have been collected from other Protozoa, especially *Chilomonas*. A preliminary paper is now in press.

(*d*) Variation and correlation in various characters of two species of fish, *Coregonus clupeiformis* and *Stizostedion vitreum*. Work on the reduction of this material, comprising something over 30,000 measurements of a variety of specific and non-specific characters in these two teleosts, is being carried on as rapidly as possible. The material was collected with special reference to a study of correlation in variation.

(*e*) The correlation between the same and different characters in the individuals of conjugating pairs of Paramecia. The work on this problem has been very successful. After many trials it has been possible to obtain abundant material of conjugating Paramecia and keep it under experimental conditions. It has now been conclusively demonstrated (1) that the two individuals of a conjugating pair of Paramecia are relatively very highly correlated with one another in respect to size (coefficient of correlation >0.5), and (2) that the portion of the *Paramecium* population in a given culture which does the conjugating is distinctly differentiated from the non-conjugating portion of the population living in the same culture at the same time, in respect to both size and variability. A preliminary paper on this work has already been published, and the complete paper will be submitted for publication very shortly.

It is expected that a paper giving the detailed results of all the studies on variation and correlation mentioned above (as well as others mentioned in the report of last year) will be submitted for publication during the coming year.

Stevens, Nettie M., Bryn Mawr College, Bryn Mawr, Pennsylvania. Grant No. 177. *Investigation of problems relating to sex determination.* $1,000.

Abstract of Report.—The experimental work on Aphids has not as yet given positive results. Histological investigation of the germ cells of *Aphis rosæ* and *Aphis œnotheræ* was completed in December, 1904, and the results published in the Journal of Experimental Zoölogy, vol. II, No. 3, August, 1905. The results of a comparative study of the spermatogenesis of several species of insects, with especial reference to the "accessory chromosome," are being published by the Carnegie Institution of Washington as Publication No. 26. The most important point in the latter paper is the discovery in *Tenebrio molitor* of a form in which sex determination by a dimorphism of the spermatozoa, not due to the presence of an "accessory chromosome," seems probable.

Tower, William L., University of Chicago, Chicago, Illinois. Grant No. 251. *Experimental investigations of the production and preservation of new character races and species in insects.* (For first report see Year Book No. 3, p. 141.) $1,500.

Abstract of Report.—In the work Mr. Tower has employed *Leptinotarsa undecimlineata*, *signaticollis*, *multitæniata*, *oblongata*, *dilecta*, and *violescens* and *Epilachnia* in Mexico, and at Chicago *L. signaticollis*, *decemlineata*, and *undecimlineata*. The experiments on *Leptinotarsa* have reached conclusive results. Four clearly distinguished classes of variations have been found—gonogenic, gamogenic, embryogenic, and somatogenic.

In *Leptinotarsa*, as far as evidence is in hand, it appears certain that new and permanent characters do not arise at any other period of life than in the germ cell or gonogenic stage. In four species of *Leptinotarsa* the important fact has been demonstrated repeatedly that it is in the growth period of the germ cells in both ova and spermatozoa that permanent modifications are produced.

Permanent modifications of several species of *Leptinotarsa* have been produced in two ways: (*a*) By sudden large variations, and (*b*) by slow accumulations of small variations, the variations in both cases being gonogenic. From experiment and also from observation in nature, the evidence is that in *Leptinotarsa* the origin of

species has been both by slow accumulated variations and by mutation; but there is no sharp line of demarkation between the two. In *Leptinotarsa* no variations are promiscuous or indeterminate. All exist in a few directions only, and the direction of fluctuating variation and of specific differentiation coincide.

New or modified characters follow in the main Mendel's laws of inheritance; but some apparently non-Mendelian characters may on further analysis be found to be Mendelian. In inheritance and evolution in this genus of beetles, characters behave as units, and, although a given "unit character" may be composed of several elements clearly distinguishable, the combinations of these elements in a "unit character" seem to predominate.

In the genus *Leptinotarsa* evolution has been determinate and heritable modifications have been produced only in those directions which are compatible with the morphology and physiology of the generic race, and they have been brought about by the direct action of environmental factors upon the germ cells (germ plasm), and by no other means. Specific differentiation takes place by slowly accumulated small variations, by rapidly accumulated large variations, and by sudden steps or mutations. The preservation of a newly appearing modification has been in accordance with the Mendelian laws, many pure races having thus been produced; and the persistence of the character in nature is determined by natural selection. Both adapted and unadapted modifications have been studied. However, many, perhaps most, of the specific characters in *Leptinotarsa* are neutral; that is, they do not appear to be directly nor even remotely useful or harmful to the species, and hence do not come under the operation of the law of natural selection. Selection can not, in any of its forms, account for the evolution of the genus *Leptinotarsa*.

Extensive experiments have also been carried on in transplanting species of *Leptinotarsa* from one habitat to another, and the conclusion has been reached that a species of conservative nature and narrow habitat is not capable of a successful widespread migration or accidental distribution; nor does it greatly increase in variability under changed conditions. Of decided importance is the clearly demonstrated fact that the variable species increase in variability under changed conditions, and of the highest importance is the increased production of inheritable discontinuous variations under such conditions.

Various phases of the variability of *Leptinotarsa* have also been studied, normal fluctuating, place, geographical, and discontinuous, and the completed work has been prepared for publication.

A study of the ecology of *Leptinotarsa* has been undertaken and the observations and data prepared for publication. The studies along this line indicate clearly that for these animals the two great ecological factors are relative humidity and heat. Of these relative humidity (not annual rainfall or precipitation of any kind) is of far greater importance than heat; while light, soil, altitude, etc., are minor factors. It is surprising to find how slight a change of relative humidity, temperature, or light conditions is necessary to inhibit the existence of many of the *Leptinotarsa* in all excepting very narrow habitats.

Yatsu, N., Columbia University, New York, New York. Grant No. 268. *Experimental study of the Nemertine egg.* (For first report see Year Book No. 3, p. 144.) $1,000.

Abstract of Report.—Dr. Yatsu reports that he has carried out under this grant a series of experiments on the egg of *Cerebratulus lacteus* during the summer of 1905 at the Harpswell Laboratory, South Harpswell, Maine. The rearing of egg fragments from various regions, effects of mechanical pressure, development of isolated blastomeres, and the like were performed at different stages. He made a careful analysis of the progressive processes of germinal regions from the unsegmented eggs up to the gastrula stage. He also clearly showed that there is a strong rugulatory tendency in the later embryos. The remaining half of his work, *i. e.*, the study of the influence of the chromosomes and cytoplasm on the morphogenic processes, will be carried on during the coming winter at the Naples Zoölogical Station.

Naples Zoological Station, Naples, Italy. Grant No. 253. *For maintenance of two tables.* (For previous reports see Year Book No. 2, p. cliv, and Year Book No. 3, p. 145.) $1,000.

Abstract of Report.—As in previous years, the grant was made to aid the laboratory in paying for the maintenance of two research-tables. The persons occupying the tables during the past year were assigned to them and notified of appointment by the director of the laboratory. (Report not yet received.)

Marine Biological Laboratory, Woods Hole, Mass. Grant No. 252. (For previous reports see Year Book No. 2, p. xlv, and Year Book No. 3, p. 144.) $10,000.

Abstract of Report.—As in the two previous years, the grant was made to aid the laboratory in paying for the maintenance of twenty research tables. The persons assigned to the tables were selected and notified of appointment by the director of the laboratory.

During the season of 1905 the following twenty-five persons occupied tables as stated:

	Date of arrival.	Date of departure.	Subject of investigation.
Andrews, Frank Marion, Indiana University	July 1	Aug. 2	Effect of alkaloids on vegetable protoplasm
Brown, Orville Harry, St. Louis University.	....	Aug. —	Anesthetics, alkaloidal salts, and certain eggs
Clapp, Cornelia M., Mt. Holyoke College	July 29	Aug. 17	Air bladder of *Opsanus tau.*
Conklin, E. G., University of Pennsylvania.	Aug. 5	Sept. —	Localization in certain eggs
Goldfarb, Abraham, Columbia University.	July 3	Aug. 25	Studies in the regeneration of certain hydranths
Hargitt, C. W., Syracuse University...	June 27	Aug. 15	Variations in the Medusæ.
Hargitt, George Thomas, Syracuse High School.	June 27	Aug. 15	Regenerative processes and structures.
Lambert, Avery E., State Normal School, Framingham, Mass.	July 1	Aug. —	Morphology of invertebrate and vertebrate brains.
Lefevre, George, University of Missouri.	July 3	Aug. 19	Parthenogenetic development in the worm.
Loeb, Leo, University of Pennsylvania.	June 22	Aug. 21	Coagulation of the blood.
Lewis, Warren H., Johns Hopkins University.	June 29	Sept. —	Localization in the eggs of *Fundulus.*
Lombard, Guy Davenport, Cornell University.	July 17	Aug. —	Investigations on the thyroid gland.
Meigs, Edward B., University of Pennsylvania.	June 30	Aug. —	Actions of the voluntary muscles of the frog.
Packard, Wales H., Bradley Polytechnic Institute.	July 7	Aug. —	Resistance of animals to lack of oxygen.
Retzer, Robert, Johns Hopkins University.	June 24	Aug. 14	Muscle-fibers of the fish heart.
Shippen, L. P., University of Pennsylvania.	Aug. 7	Aug. —	Influence of eosin upon the development of eggs,
Snowden, Louise Hortense, University of Pennsylvania.	July 1	Sept. —	Embryology of *Crepidula.*
Stevens, Nettie M., Bryn Mawr College.	Mar. 24	Mar. 30	Insect spermatogenesis.
Stickney, Malcolm E., Denison University.	June 27	Aug. 14	Anatomy of grasses.
Strong, R. M., University of Chicago.	Aug. 2	Aug. —	Colors of birds.
Terry, Oliver P., St. Louis University..	June 28	Aug. 15	Galvanotropism of *Volvox.*
Wallace, Louise Baird, Mt. Holyoke College.	Aug. 15	Sept. —	Spermatogenesis of the spider.
Whitney, David Day, Columbia University.	June 6	Aug. 26	Segmentation of certain fertilized eggs
Wilson, Edmund B., Columbia University.	Aug. 2	Sept. —	Sex-determination by study of chromosomes.
Yamanouchi, Shigeo, University of Chicago.	July 13	Aug. 19	Cytological study of the algæ.

The assistant director of the laboratory, Dr. Frank R. Lillie, sent the following statement of the investigators at the laboratory during the season of 1905; thirty-five institutions were represented by 69 investigators:

Zoölogy:
- Occupying rooms 43
- Occupying tables 6

Physiology:
- Occupying rooms 10
- Occupying tables 2

Botany: Occupying rooms 8

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